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SPEED UP YOUR LENS SYSTEMS*

WILLIAM C. MILLER**

Summary.—*The tendency of bare glass surfaces to reflect light has always presented a serious problem in optics. New discoveries in the field of physics have resulted in methods of reducing these light reflections. One of these methods has proved practicable for general use in optical equipment. The reduction of reflections in treated systems has been so great that ghosts and flares are rarely encountered. The light no longer reflected by the glass surfaces is transmitted by the optical systems, increasing their efficiency. Camera lenses treated with the new process show an increase in speed of nearly a full stop. New applications of the process are being found almost daily.*

At times the reflectivity of the polished surface of optical glass may have its uses. More often, however, the applications of optical glass are of such a nature that the surface reflection is a decided disadvantage. It reduces the efficiency of optical systems by robbing the transmitted beam at every air-glass surface. Furthermore, the light thus subtracted from the primary beam may appear again in the form of flares where it is not wanted. For example: in a modern photographic lens at every air-glass surface from 4 to 6 per cent of the incident light is reflected and the transmitted beam is correspondingly reduced in intensity. After passing several surfaces, say, 8, as in the case of the Astro Pan Tachar, Baltar, and Cooke Speed Panchro lenses, the transmitted beam has been reduced to about 64 per cent of the original intensity. The greater the number of air-glass surfaces in a system and the higher the average index of refraction of the elements, the greater is this loss. Fig. 1 shows the losses suffered in various lens systems in terms of the number of air-glass surfaces.

About 50 years ago H. Dennis Taylor observed that certain optical glasses acquired a tarnish after prolonged exposure to the air. This tarnish was in the form of a colored film. Becoming interested in these surfaces, Taylor made measurements on them, and found that this tarnish was not reducing the light transmission of the lens but on

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 19, 1940.

** Paramount Pictures, Inc., Hollywood, Calif.

the contrary was increasing it by reducing the amount of reflection from the affected surfaces. This phenomenon and its potentialities so intrigued Taylor that he began a series of tests to determine whether the tarnish could be stimulated artificially by chemical means. His work was only partially successful. The number of kinds of glass which he could treat was very limited and the reduction in reflectivity which he obtained was not sufficiently great to prove of practical value.

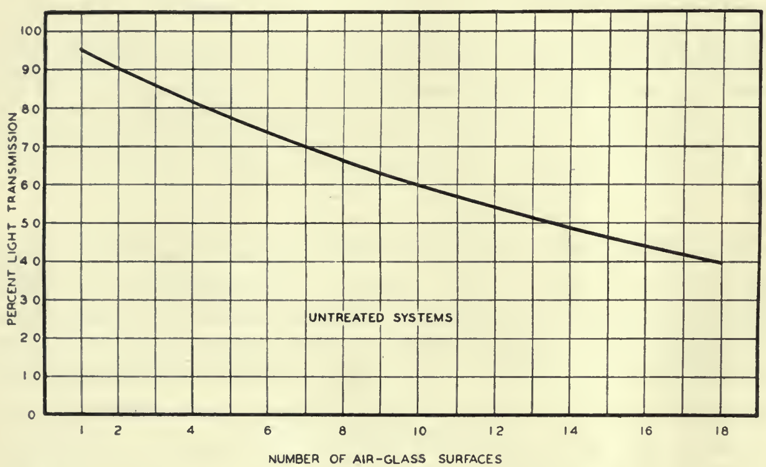

FIG. 1. The light transmission of optical systems in terms of the number of air-glass surfaces involved. A simple magnifying glass having two surfaces transmits about 90 per cent of the incident light. Common camera lenses having six surfaces transmit, on the average, about 73% of the incident light exclusive of that lost by absorption. This curve is computed for systems having an average reflectivity of 5 per cent at each air-glass surface. For systems having a higher average reflectivity, the losses would be greater, and *vice versa*.

The idea did not die at that point, however, for others took up this work. Most notable among these experimenters were Kollmorgen, Kellner, Wright, and Ferguson. By them the chemical method has been brought to a point where it now has practical value. Certain glasses, notably the dense lead flints, can be treated with a nitric acid bath and the surface etched in such a manner that reflections are reduced without producing scattering of the transmitted beam. The chemical treatment dissolves out minute particles of the lead oxide lying near the surface of the glass. The removal of this material results in the formation of tiny cavities. The treatment is

carried on until the etching has penetrated to a prescribed depth. When the lens is dried, air penetrates these cavities, whose dimensions are smaller than a wavelength of light and, therefore, produce no scattering effect upon the incident light. The result of the penetration of the air into the surface of the glass is that the average index of refraction of the surface layer is reduced. A light-ray incident upon such a treated surface encounters this thin layer of material of low index, with the result that reflection is reduced. However, the proportions of air to glass in the etched layer can not be made great enough to produce the maximum effect and the reduction of reflections is not as great as one might expect was physically possible.

There are three reasons why the chemical method has not been widely applied. First, the reduction of reflections by the chemically treated surface is low; second, the types of glass that can be treated are limited; and third, the process can get out of control and ruin expensive optical elements.

Realizing the seriousness of these limitations, Dr. John Strong, of the California Institute of Technology, began an investigation of this phenomenon in 1935.[1] It was his aim to find a method that would be more effective in reducing the reflections from glass surfaces and would be independent of the chemical nature of the surface upon which it was to be applied. Also, it was his aim to find a process whose effect could be removed when desired, leaving the glass in its original condition. This aim was achieved by a physical rather than a chemical treatment of the surface.

Dr. Strong pointed out on theoretical grounds that a film $^1/_4$ wavelength in thickness deposited on the glass surface will produce the maximum effect on the amount of light reflected. Furthermore he showed that if the index of refraction of the deposited film were equal to the square-root of the index of refraction of the glass upon which it lies the intensity of the normally reflected light would be zero. The light not reflected by the treated surface is transmitted. However, for ordinary glasses the film must consist of a material having an index of about 1.25, a value less than that of any stable solid substance. Allowing certain compromises in the hardness and durability of the film, he was able to approximate that index closely enough to eliminate 85 per cent of the surface reflection.

This low index of refraction was obtained in a novel way. A film of suitable material was deposited on a glass surface by the high-vacuum evaporation technic. He discovered that the film could be

deposited in a porous form so that air was able to penetrate it. Thus the film exhibited an index which was an average of the index of the evaporated material and that of the included air. By controlling the factors involved in the evaporation of the film he was able to get an index very nearly equal to the square-root of the index of the glass. The success of Dr. Strong's experiments is attested by the fact that he succeeded in reducing the reflectivity of plate-glass from 4 to 0.6 per cent. For plates treated on both surfaces this corresponded to increasing the transmission from 92 to 99 per cent.

Subsequently, Dr. Katherine Blodgett,[2] of the General Electric Laboratory, found another and quite different physical means of achieving the same results. She found that by dipping glass 46 times into a water bath covered with a monomolecular film of cadmium arachidate and arachidic acid, a film of the required thickness was built up on the glass. This film has too high an index in its original form, but by washing it in hot acetone Miss Blodgett reduced the index to the proper value. This treatment with acetone dissolved out the minute globules of arachidic acid, leaving a porous film of cadmium arachidate which, with the included air, have exactly the required index.

Films obtained by Miss Blodgett's original process are exceedingly delicate and can therefore be used only on the most protected surfaces. They will not stand heat and can not be cleaned or touched in any way. Furthermore, after having been washed with acetone, the films are so completely relieved of all grease that they have a great affinity for any oils that come in contact with them. Many dust particles that float in the air are laden with oils and greases. When such a fleck falls upon a cadmium arachidate-treated surface the film absorbs the oils from the dust, with the result that a small surrounding area changes its refractive index and loses its efficiency. As dust accumulates, therefore, the treated surface develops a large number of small glossy spots which have returned to the original index of the untreated glass.

In all three processes described, the low-index surface layer must be $^1/_4$ of a wavelength in thickness to reduce the reflection of light of that particular color. Since the films obviously can not be $^1/_4$ wavelength thick for all wavelengths at once, the reduction of reflectivity must be a maximum for one color and less for others. In practice this color differential is not serious. Certain steps can be taken to reduce it materially in photographic lenses in the few cases where an

excess of a few per cent of one color in the transmitted beam is undesirable.

Comparison of the two physical methods, the one by Dr. Strong and the other by Miss Blodgett, shows that at the present time the one discovered by Dr. Strong is the most promising for general use. In view of this it has attracted the attention of several workers; notable among them are Cartwright[3,4] and Turner,[3] who experimented with various materials, some of which offer certain advantages.

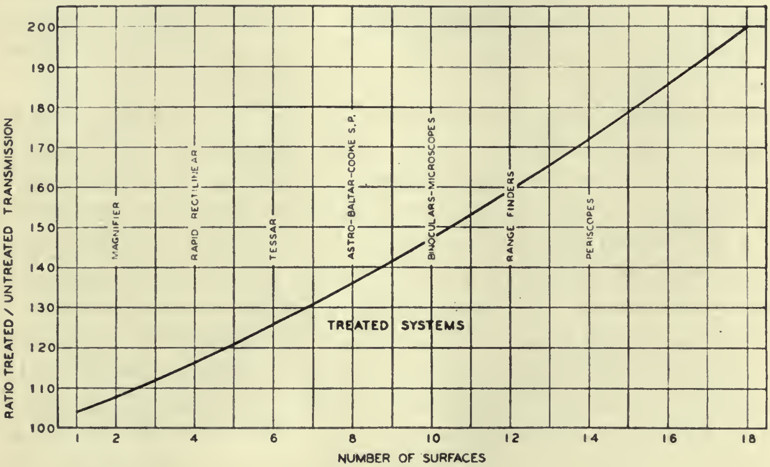

FIG. 2. The light-transmission ratio of treated to untreated systems in terms of the number of air-glass surfaces involved. This curve represents the gains which can be realized by treatment of systems normally reflecting an average of 4 per cent at each air-glass surface. Several examples are noted on the graph of common optical systems composed of the indicated number of surfaces.

A film deposited in a manner which will give the greatest possible reduction to reflections is so porous and soft that it has little mechanical strength. But by a compromise whereby one sacrifices some efficiency, increased durability is obtained. The resulting films are much more valuable for practical applications. The compromise films still effect reductions of 75 per cent in the reflectivity of glass surfaces and exhibit properties which are particularly well balanced for general use.

At the request of Paramount Pictures, Dr. Strong treated a 3-inch Astro Pan Tachar lens with which the first tests were made to deter-

mine the value and practicability of the process for motion picture work. These tests consisted of optical bench measurements and photographs of scenes made under severe production conditions. The results of the tests were so remarkable that a full set of camera lenses and several projection lenses were treated by Dr. Strong's process and placed in production. Further tests were made under very adverse conditions to determine just what new possibilities the treated lenses presented.

Photometric measurements show that treated lenses transmit about 40 per cent more light than identical untreated lenses. Reference to Fig. 2 shows that this measured value compares favorably with the gain for an eight-surface system predicted from theoretical considerations.

Photographic results obtained on a production set, however, indicate that the effective speed of the treated lenses has been increased by a larger amount than that indicated by photometric measurements. For example, the experience has been that scenes shot with the treated lenses printed between 4 and 6 Cinex printer-lights lower than the identical scenes made with untreated lenses. An average difference of 5.3 printer-lights indicates an increase of 58 per cent in transmission. This apparent discrepancy is probably due to the difference in the methods of judging relative density in the two cases. It is also felt that the type of scene being photographed has some effect upon the apparent speed difference between treated and untreated lenses. Much more data than are now available must be studied to determine accurately the true effect of this treatment upon photographic speed.

Optical bench tests show that the definition and resolving power of treated lenses are increased. There is also a very noticeable improvement in image contrast and brilliance. The color correction of the lens is unchanged since this characteristic depends upon factors in no way affected by this treatment.

The depth of focus at a given aperture is not changed since depth of focus depends entirely upon the linear aperture of the lens, which dimension is unaltered by the treatment. However, since the light transmission of a treated lens is increased at fixed light levels on a scene, the lens can be correspondingly stopped down. This reduction of aperture will add to the depth of focus of the treated lens.

Reducing the reflectivity of the glass surfaces of the lens reduces the diffused light normally reaching the photographic film. This re-

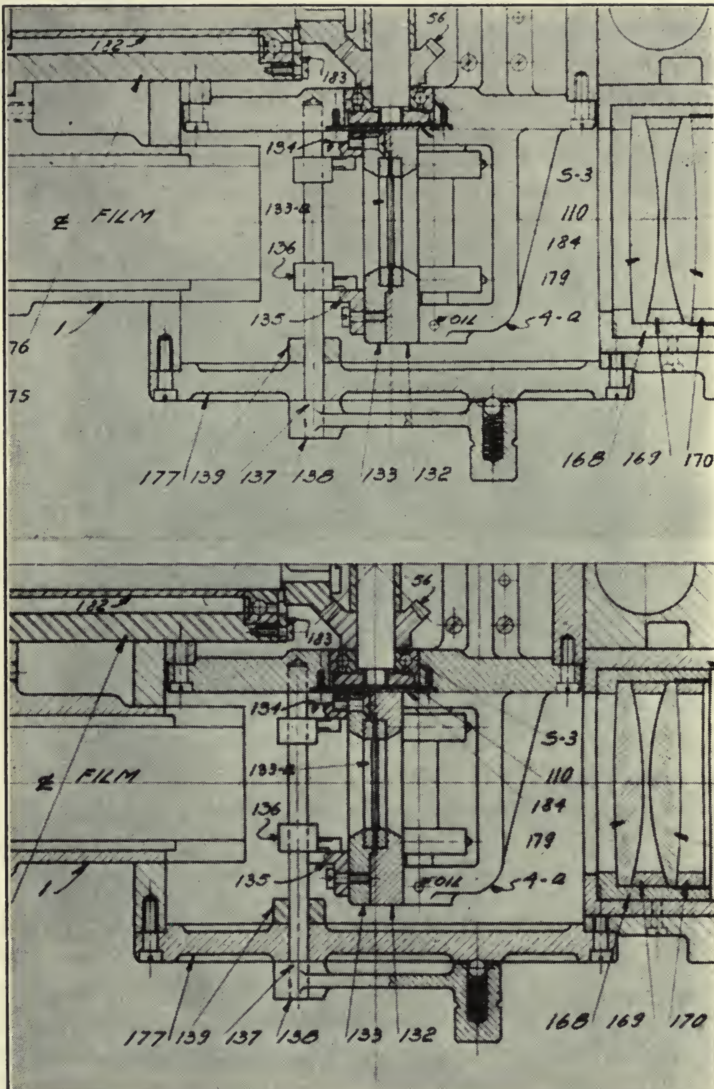

FIG. 3 (*Upper*). Photograph of a pencil drawing made with an untreated lens.

FIG. 4 (*Lower*). Photograph of the same drawing under identical conditions made with a treated lens. Notice the increased contrast and strength of the reproduction compared to that shown in Fig. 3.

sults in a surprising increase in the clarity with which low-key scenes are reproduced. The halftone reproductions accompanying this article illustrate the effects obtained, although the original photographs exhibit these effects more clearly than do these reproductions.

Although the benefits of treated lenses are particularly noticeable in low-key scenes due to low light-levels, they are also highly beneficial in ordinary photography. As an example, consider the application

FIG. 5. The same subject as shown in Fig. 6, photographed with a treated Astro Pan Tachar lens, showing its freedom from flares. In the original negative there was one faint flare still visible which has been lost in the process of reproduction, which is responsible, also, for the increased size of the halo around the sun's image in this picture. It was actually no larger with the treated lens than with the untreated one.

of treated lenses for copying work. Anyone who has endeavored to copy a pencil drawing in black and white will be interested in comparing Figs. 3 and 4, one made with a treated lens and the other with an identical untreated lens. The increased contrast with which this type of subject is rendered is a splendid example of the advantages offered by treated optics. Other types of copying are similarly facilitated by treatment.

Internal reflections are responsible for the flares and ghosts so frequently encountered in photographic work. These flares are pro-

duced by light originating from a bright object being reflected from one surface of a lens element and then being redirected by second reflection toward the photographic film. Flares are strong when the reflecting lens surfaces have curvatures such that the redirected rays reach the film as a concentrated beam of light. By reducing the reflectivity of the surfaces of the lens elements to $^1/_4$ of their original value, a beam reaching the film after two reflections will be weakened

FIG. 6. An example of the lens flares obtained by shooting into the sun with an untreated Astro Pan Tachar lens. These flares are due to the inter-reflection of light-rays between the elements of the lens. The black line going through the sun is a distant cable purposely silhouetted to supply an object for comparison in this scene.

16-fold. The intensity of the flare beam after four reflections from treated surfaces—three being an impossible condition—is reduced in intensity 256-fold.

Figs. 5 and 6 show the results obtained by photographing directly into the sun with two identical lenses, one treated and one not. In the former instance, there is only one very faint flare, while with the latter there are thirteen strong ones in the original negative. If this freedom from flares can be accomplished with the sun as a source, it goes without saying that little trouble will be encountered from street

lights, automobile headlights, bright windows, or artificial lights in rooms.

Glass diffusion disks and filters are frequently the source of flares and ghosts. Treatment of their surfaces with a soft coating would cause occasional trouble due to the difficulty of keeping these films free from blemishes. Located, as they often are, some distance from

FIG. 7. Photograph made with an untreated lens at very low light levels with an untreated $f/2.3$ Astro Pan Tachar lens. The light-intensity was purposely lowered to a point where satisfactory results could not be obtained with normal lenses of that speed. Compare the quality with that of Fig. 8, made with an identical treated lens with all lighting conditions remaining the same.

the optical center of the camera lens, such blemishes would endanger the quality of the picture. To provide for the treatment of such surfaces as well as for the outside surfaces of lenses subjected to severe treatment, Dr. Strong has developed a method of applying a much harder and more durable film. Although the efficiency of this toughened film is less than that of the softer coating, it is still effective in reducing reflected light. Diffusion disks in use at Paramount, treated with the harder coat, show a reduction of reflections of 40 per cent per surface.

As an illustration of the increased definition and contrast obtained with treated lenses, cameramen find it necessary to use stronger diffusion. Unquestionably part of this effect is due to the reduction of scattered light which previously gave a false impression of diffusion. Now, however, with treated systems more nearly true diffusion will be realized.

Gains made possible by treating camera lenses can also be realized with projection systems. A most promising application of the process

FIG. 8. The same subject as shown in Fig. 7, photographed under identical conditions with a treated Astro lens at the same aperture as that used for Fig. 7. Notice the increased brightness of the scene and the improved quality and definition obtained with the treated lens.

is the treatment of projection lenses used in process photography. Here the need for more light is constantly felt. With the treatment applied to some of the modern eight-surface projection lenses, needed increases in screen illumination will be obtained without the sacrifice of image quality normally associated with increased optical speed. Recent tests made at the Paramount Studio show an increase of 50 per cent in the screen brightness when treated projection lenses were used. This gain appears higher than that indicated in Fig. 2 for an eight-surface system, because the losses by reflection in that parti-

cular make of lens are unusually high due to the presence of elements having a high index of refraction and several highly curved surfaces.

It is certainly interesting to note that by this relatively simple treatment, screen illumination has been increased 50 per cent at one jump, while in the past much time and money have been expended to achieve far smaller gains.

Due to the many steps involved in producing a finished process shot, it is only with great care that good quality is maintained in the projected portion of the finished picture. The gains in definition and brilliance of the image obtained with treated lenses will greatly facilitate this method of photography and add to the quality and scope of the art.

This treatment would also appear to present advantages in sound recording where light transmission, definition, and contrast of image are vital At the present time several groups are experimenting with treated sound recording lenses. However, no information is yet at hand concerning the results obtained. Undoubtedly interesting reports will be forthcoming in the near future.

Although the material presented so far in this paper has to do largely with the application of Dr. Strong's process to photographic objectives, in reality this is only one division of the field of possible applications. Visual instruments, such as binoculars and microscopes, give striking evidence of the practical use to which this treatment can be put.

In the case of both binoculars and microscopes, the only aid which these instruments offer to normal vision is magnification. No instrument can increase the intrinsic brightness of an extended object or increase the contrast. But, owing to the losses by absorption in the glass and by reflection of light at the glass surfaces, such instruments reduce the brightness of an object and greatly detract from the contrast and brilliance of the field. The excellence of certain makes of binoculars depends largely on clever design managed so that the effects of reflection are minimized. Moderately priced binoculars with treated surfaces will frequently be found to give better aid to vision than more expensive untreated instruments. Light transmission in treated glasses is greatly increased, as can be seen by reference to Fig. 2. At the same time, the contrast is increased through the elimination of light scattered throughout the system.

This new technic of reducing the reflection of glass surfaces promises to come nearer to revolutionizing the uses and applications of

optical glass than any other developments of the past several decades. Now for the first time it is possible to increase the speed of optical instruments and photographic lenses and improve image quality simultaneously.

Although the process is in its infancy, the widespread interest which it has already aroused indicates the pressing need for the improvements that the treatment makes possible and the eager welcome which it will receive from all those who depend upon optical equipment either for profit or pleasure.

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DISCUSSION

MR. KURLANDER: How much farther could the lens be stopped down, also taking into account the reduction in lens flare?

DR. RAYTON: There are two factors involved. One is an increase in light transmission, with respect to which I feel fairly familiar. There is another factor, referred to in Mr. Miller's paper, concerning which I feel incapable of reaching any opinion on a quantitative basis.

I would like to express my pleasure at this paper that Mr. Miller has prepared. He has done an excellent job of laying this situation before you. I think his figures for gain in transmission are certainly top figures. I had the pleasure of speaking with Mr. Miller recently, when he referred to the projection lens that he had found to yield a 50-per cent increase in transmission. We had a little friendly disagreement as to whether or not that was possible. He could say only that his measurements indicated that, and I could only say that I found it a little difficult on theoretical grounds to see how it could reach that high figure. The matter was left there. Perhaps it is not greatly important. I think that in general his figures are justifiable, and that an increase in the light transmission of a photographic lens with eight surfaces of 35 per cent or that order is perfectly possible.

The stops in a photographic lens are usually arranged so that the difference in exposure is 2 to 1 as we pass from one stop to the next, so that on the basis of increased transmission, the amount of stopping down that one can expect is something less than half a stop.

In the *American Cinematographer* for March, 1940, Mr. W. Stull claimed that it was possible to reduce the aperture by one full stop in a lens with treated surfaces. The explanation was based on some factors in addition to simple increase in transmission.

Mr. Miller touched upon several other very interesting points that, if developed, could run the discussion on endlessly. There is the possibility of extending this treatment to other types of optical instruments. It has a fascinating future, but I do not think it is necessarily going to cure all the difficulties or reduce all the problems of the lens designer.

DR. JONES: I think the thing Dr. Rayton has been driving at is, perhaps, a little further discussion on the effects of what we call flare light on picture quality; and by that I mean light which is uniformly distributed over the surface of the negative material. We must distinguish between that and the thing we call flare spots. Undoubtedly, this treatment is extremely efficient in eliminating these undesirable flare spots.

When you go into the effect of flare light distributed over the surface of the materials, quite uniformly in many cases, the problem becomes quite complicated because we can not give a general solution and state exactly what will happen in all cases.

Flare light is not all due to reflection from the lens surface. In any optical system, such as a camera, there are the lens, the diaphragm blades, shutter blades, in many cases, and, in the case of hand cameras, bellows. There is the barrel in which the lens is mounted. All these contribute somewhat to the magnitude of the flare light. So, as I see it, the complete elimination of reflections from the lens surfaces would not, in general, completely eliminate flare.

Moreover, the amount of flare on the photographic surface will depend upon the characteristic of the scene being photographed; and upon the light distribution of the entire field to which the lens of the camera is subjected. Of course, it is common practice to use lens hoods. Those hoods reduce the flare light, because they protect the lens from a large portion of the peripheral field.

As I said before, there is no general solution of the flare problem. It must be based upon specific conditions—the entire optical system and what is out in front of it. A quantitative evaluation of what good will result from this method would have to be based upon a statistical study of a large number of scenes.

Always, we must consider, to some extent, the influence of this flare light, or its absence, upon the quality of the final picture; and the only way I know to do that, other than by making practical tests, is to apply the tone reproduction analysis.

MR. EDWARDS: There is one other condition. In the Super-Simplex, at least the later models, and in the *E-7*, the light goes through not only the lens, but also a very thin wafer of Pyrex glass situated in front of the aperture. If it is possible by the corrosion or etching method to save 2 or 3 per cent on each surface, etching this glass would give us a total of 5 or 6 per cent gain in light transmission.

DR. GAGE: If the hard coating can be successfully applied to the thin wafer or to the condenser lenses, and so much dirt does not get onto them that frequent scrubbing is necessary so that the coating is worn off, it would be advantageous in letting more light through.

Treating any of the condenser elements before the light strikes the film would give a slight increase in light. When we get to the objectives, the additional flare due to multiple reflections has a great deal more to do with the quality of the picture, so that it is doubly important to treat the objective.

PROGRESS IN PROJECTION LIGHTING*

W. C. KALB**

Summary.—*The carbon arc has had an important part in the progress of the motion picture industry from the time of its origin to the present day. This narrative of the various improvements and developments which have kept the carbon arc in its preferred position as a source of projection light is presented in chronological sequence. Data are given relative to the progress made along five lines of improvement: intrinsic brilliancy of the crater, quality of light produced, volume of light on the screen, efficiency of light production, and economy of operation.*

Three physical properties of a widely distributed element lie at the very foundation of the motion picture industry and have had much to do with its remarkable record of progress. This element is carbon. The properties which are so vital to this industry are: good electrical conductivity, the fact that carbon does not melt, and the further fact that it can be raised to a temperature of more than 3600°C before changing from the solid to the vapor form. These physical properties permit small rods of carbon to be used as the terminal electrodes of the electric arc producing a light which rivals, in brilliancy and whiteness, the light of the sun itself. When Sir Humphry Davy in his classic experiment early in the 19th century produced the first electric arc between carbon electrodes he could have had no thought of the importance his discovery was to have in the development of an industry to be founded almost a century later. Yet the phenomenal strides made by the motion picture industry in its relatively few years of existence were made possible by the adaptability of the carbon arc to its expanding needs.

Many other factors, including technical advances in other lines, have had important parts in the development of the motion picture industry over a relatively short span of years into one of the major industries of the country. The artistry of directors, cameramen, and actors have played a large part. The sagacity and courage of the

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received May 21, 1940.

** National Carbon Co., Cleveland, Ohio.

industry's executives have contributed largely to its record of progress. These factors involving personalities have been given much publicity and have tended to overshadow the improvements in the carbon arc and its utilization which have likewise had a vital part in making possible the tremendous growth that has been realized.

The optics of motion picture projection are such that a light-source of small dimensions and very high intrinsic brilliancy is essential. No light-source has been available throughout the history of the industry which satisfies these requirements so well as the carbon arc. The crater of the positive carbon offers an essentially flat field of light emission, sufficiently uniform in brilliancy over its entire area to provide a satisfactory uniformity of illumination on the largest screen. Due, however, to the enormous difference in area between the screen and the source of projection light, and to losses encountered in the optical system, the brilliancy of the light-source must be millions of times that of the light reflected from the screen. It is therefore but natural that, from the first commercial exploitation of motion pictures, the carbon arc should have been selected as the source of projection light. For the carbon arc, at that time to be seen on almost every street corner, was by far the most brilliant source of light man had then produced. Subsequent improvements, the product of constant laboratory research, have kept the arc abreast of the needs of this growing industry.

The first projection lamps burned the carbons in a position slightly inclined from the vertical, with the positive carbon in the upper position so that the brilliant positive crater was turned partially toward the condenser lens which focuses the light on the film aperture. Further exposure of the positive crater to the condenser lens was accomplished in this type of lamp by adjusting the position of the negative carbon so that the tip of the positive carbon burns off on one side. From the first adaptation of the arc to projection there has been steady progress toward more and more efficient production and utilization of projection light. Developments in projector carbon manufacture have adapted the arc to more efficient optical systems and, combined with improvements in the lamps themselves, have successfully met the increasingly critical attitude of theater patrons and kept the carbon arc in its preferred position as a source of projection light.

The need for more light, first to increase the brightness of the screen image, and then to meet the needs of larger theaters, resulted

in the use of larger carbons and higher arc currents. Steadiness of the light was improved, first by making the positive carbon in the form of a thick-walled tube with a central core of softer, neutral carbon. This is done by extruding the plastic carbon mix from a huge hydraulic press leaving a central opening in the carbon as may be seen in Fig. 1. After these "green" carbons have been baked and cut to length, the central opening is filled with core material in an automatic coring machine. Further improvement in steadiness of the arc was effected by using a metal-coated negative carbon, consider-

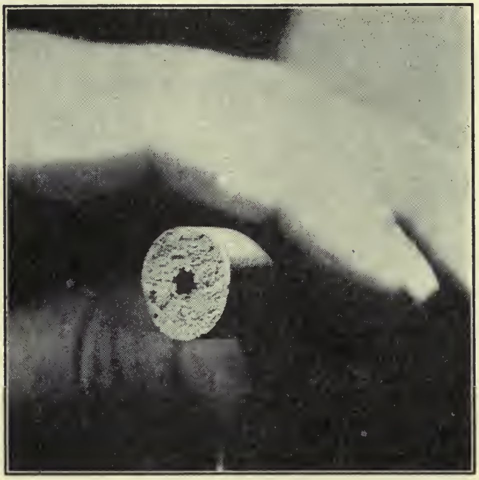

FIG. 1. End of "green" carbon showing central opening for core.

ably smaller in diameter than the positive. Fig. 2 is a drawing of this improved trim which indicates also the form of the positive crater. These improvements in the carbon trim, combined with improvements in optical systems, substantially increased the efficiency of the types of projection lamps then universally used.

By this time motion picture theaters were getting away from the limitations to capacity which the audible range of voices from the stage had previously imposed on the theater. Houses seating 3000 and 4000 patrons were being built, screens were enlarged for the benefit of the patrons in the rear seats, and the need for still more screen light became urgent. Fortunately, a new principle upon which the carbon arc could be operated was discovered at about this time.

This has been aptly termed the "high-intensity" arc and, for distinction, the term "low-intensity" arc has been applied to types of carbon arcs previously in use.

The low-intensity, neutral cored carbon arc is seldom operated at a current-density much over 200 amperes per square-inch in the positive carbon. The light used in projection all comes from the incandescent crater face of the positive carbon, the brilliancy of which is determined by its temperature. Since carbon vaporizes at a temperature of about 3675°C, further increase in current beyond the value which produces this temperature does not increase the crater temperature and brilliancy but serves only to consume the carbon more rapidly. The philosophy is the same as that of the three-minute egg. You can turn up the gas and boil the water away more rapidly, but the temperature remains at 212°F in the pan and the three-minute egg is still a three-minute egg. In practical operation the upper limit of crater brilliancy in the low-intensity, d-c arc is approximately 175 cp per sq-mm.

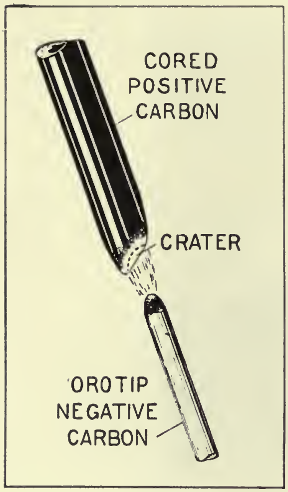

FIG. 2. Drawing of carbon trim for d-c low-intensity condenser - type lamp.

In the high-intensity arc the core of the positive carbon is relatively larger than in the low-intensity arc and contains certain rare-earth materials which become highly luminescent under the action of the electronic bombardment in the arc stream. The current-density in the positive carbon is also increased to values of more than 800 amperes per square-inch. At this high current-density the crater of the positive carbon burns out to a deep cup-like form within which the vapors of carbon and core material appear to be retained and possibly compressed by the stream of electrons from the negative carbon, and so raised to a temperature considerably above the vaporizing temperature of carbon. The effect of this action is to produce a brilliancy within the crater cup several times that possible at the positive crater of the low-intensity carbon arc. In these original high-intensity lamps the negative carbon was inclined to the positive and the

latter rotated to maintain a symmetrical crater form. This method of operation is still used on lamps of higher power. Fig. 3 shows the appearance of this type of high-intensity arc as viewed from the side.

The application of the high-intensity arc to projection through the medium of a condenser lens optical system gave three to four times as much light on the screen as had previously been available and

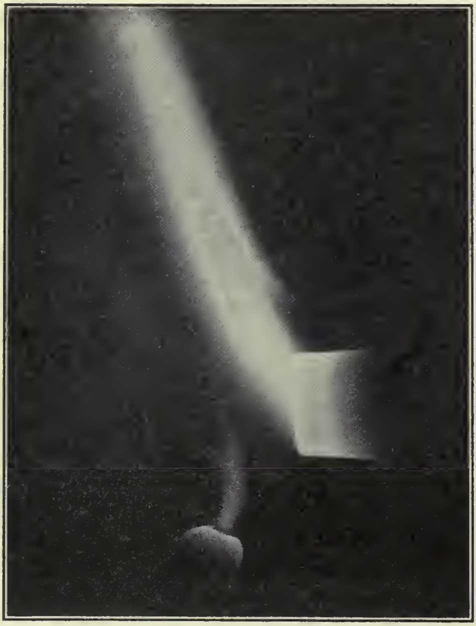

FIG. 3. Photograph of d-c high-intensity arc in condenser-type lamp.

further improved the efficiency of light production. Later improvements in the condenser lens system for high-intensity lamps have raised the efficiency of light production to more than five times that obtained from the earliest projection lamps. Thus improved, these lamps deliver possibly forty times the amount of light projected on the screens of the first motion picture theaters.

One of the principal benefits realized from this enormous increase in screen light is the improvement in general illumination of the theater which followed. With only 200 lumens on the screen it was necessary for theaters, even of nickelodeon dimensions, to be operated in almost

complete darkness. Many will recall the days when red exit lights were the only supplement to the dim illumination resulting from screen reflection. However, forty-fold increase in screen illumination, even on much larger screens, permits a clear picture to be shown in the presence of a comfortable level of general illumination, and the large theaters which adopted high-intensity projection were prompt in capitalizing this advantage.

Small theaters could not afford these large high-intensity lamps, nor did they have need for so great a volume of screen light. The development of the reflector-type low-intensity lamp, however, brought to the small theater a considerable measure of improvement in screen light and permitted the installation of some general illumination. In place of the condenser lens which, in the old type low-intensity lamp, picked up a light cone of approximately 45 degrees, the reflector lamp uses an elliptical mirror to pick up the light from the positive crater and focus it on the aperture plate. Both carbons are mounted in a horizontal position with the crater of the positive carbon facing the mirror. By the adoption of this optical principle the light pick-up was increased from 45 to 120 degrees, and projection efficiency greatly improved. The needs of theaters requiring more light than this, but not large enough to require the condenser-type high-intensity lamps, were met in a similar manner by using the mirror principle with the high-intensity arc, in what is commonly termed the "Hi-Low" lamp. In this lamp the negative carbon is inclined to the rotating positive, but at a much smaller angle than in the condenser-type high-intensity lamp. The positive carbon used is 9 mm in diameter, and the arc is operated at a current of about 75 amperes; whereas the condenser-type lamp uses a 13.6-mm positive and an arc current of about 125 amperes.

In the early 30's the increasing attention being given by the public to the subject of adequate illumination was becoming a serious problem to a large number of motion picture theaters. Theaters using high-intensity projection had demonstrated the feasibility of maintaining a level of general illumination permitting comfortable vision on the part of patrons entering from the street or the brilliantly lighted lobby. Theatergoers were no longer willing to grope and stumble to their seats without complaint or to accept screen projection of inferior quality. A clear screen image in the presence of adequate general illumination requires a screen brightness of at least 7 foot-lamberts and preferably more. Low-intensity projection lamps

will not provide this amount of light on the screens of many neighborhood houses that are, however, not large enough to require high-intensity lamps capable of giving 7 foot-lamberts on screens considerably more than 20 feet in width. Nor could a three- or four-fold increase in the cost of lamp operation be justified by these theaters of relatively small seating capacity. It was at this psychological time that the "Suprex" carbon was developed by the laboratories of National Carbon Company, Inc., and projection lamps of simplified design were produced to take advantage of its possibilities. The optical principle in these lamps is the same as that of the low-inten-

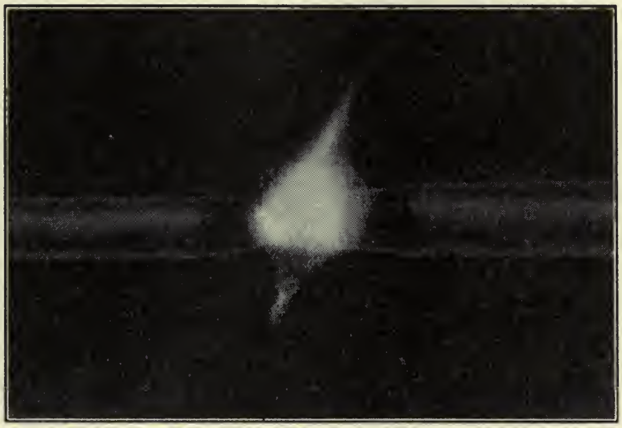

FIG. 4. Photograph of "Suprex" type arc.

sity reflector arc lamp, but a still larger angle of light pick-up has been adopted and improvements have been made which considerably increase the projection efficiency. These lamps use small-diameter, copper-coated, high-intensity carbons operating without rotation in a horizontal position, as seen in Fig. 4. Admirably meeting the needs of theaters of intermediate size, they have even reached into the fields formerly occupied by the earlier types of high-intensity lamps. These simplified high-intensity lamps occupy the wide gap between the maximum light output of the low-intensity lamp and the very high light output of the original high-intensity types. Furthermore, the cost of operation is so low on these simplified high-intensity lamps that the advantages to be gained from increased screen light

and better general illumination more than offset the slight increase over the operating cost of low-intensity lamps.

Another factor which gives further advantage to theaters using high-intensity projection is the growing popularity of color features and the critical attitude of theater patrons toward accuracy of color reproduction. The audience sees on the motion picture screen only those colors that are present in the projection light. If certain colors are absent from the light, the dye on the film can not put them on the screen. Excess of certain colors likewise distorts the natural hues of color features. High-intensity carbon arc projection assures an evenly balanced light with all colors present in essentially equal intensity.

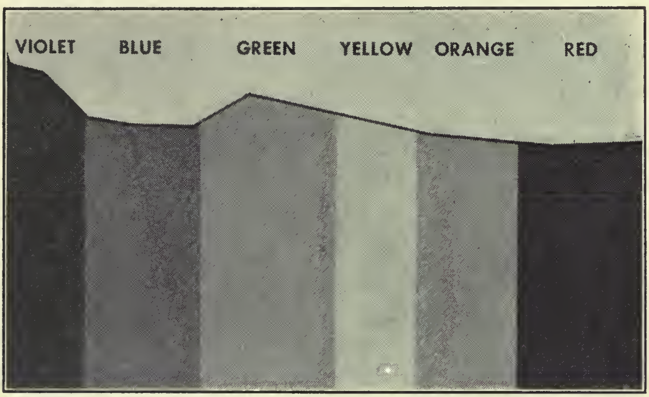

FIG. 5. Color distribution of light from high-intensity carbon arc.

This is apparent from the chart of color distribution shown in Fig. 5. This is the quality of projection light for which theatrical color-film is processed. It is the only quality of light that gives natural color reproduction with standard 35-mm color-film. Low-intensity lamps give a light of yellowish tint which distorts color values and detracts from the realism and beauty of color features. The high-intensity arc, emitting essentially equal intensities of all the spectral colors, reproduces all hues and tints with remarkable accuracy.

Even though some theaters of small seating capacity may not have felt the need for the greater volume of screen light that has been experienced by houses of greater capacity, they are feeling the need for a better quality of projection light than low-intensity lamps provide. The snow-white light of the high-intensity arc means just as much in

the way of satisfied patronage and increased attendance to these small theaters as it does to the large down-town houses, and the latest development in projection equipment, the new low-wattage high-intensity arcs, puts high-intensity projection right in the lap of this smallest member of the theater family. Both a-c and d-c lamps are now on the market in which the power consumed at the arc is of the order of one kilowatt, and the cost of operation correspondingly low. The operating cost with these new lamps is less than that of the low-intensity lamp although the light output is 50 to 80 per cent greater and the efficiency of screen light production the highest yet obtained. Cost of operation is therefore no longer a justification for any theater, however small, doing without the increasingly important advantages of high-intensity projection.

The new a-c high-intensity lamps avoid the flicker sometimes observed when the a-c high-intensity arc is operated on 60-cycle alternating current by operating through a frequency changer which supplies 96-cycle alternating current to the arc. The cut-off ferquency of the two-blade shutter at standard projection speed is 48 cycles per second. With a 60-cycle light-source, this results in a 12-cycle beat or fluctuation in the screen light which, under certain conditions, may be disturbing to the observer. By using a frequency of 96 cycles at the arc one full cycle of current occurs during each 90-degree shutter opening, and disturbing flicker is eliminated. Regardless of the phase relation between the current and the shutter, the same amount of light is passed during each period the shutter is open.

The new d-c high-intensity lamps are operated at 30, 35, and 40 amperes arc current with 27.5 volts or less across the arc. This low arc voltage has been made possible by the development of an improved negative carbon which permits operation at short arc length without the formation of a carbide tip. The optical principle in these new low-wattage high-intensity lamps is the same as that used in the simplified high-intensity lamps which have achieved such popularity during the past four or five years.

Reviewing on a more specific basis the foregoing narrative of progress, five lines of improvement will be noted. These are (*1*) intrinsic brilliancy, (*2*) light quality, (*3*) volume of screen light, (*4*) efficiency of light production, and (*5*) economy of operation.

(*1*) *Intrinsic Brilliancy.*—In the early days of motion picture projection, methods of light measurement now available had not come

into use, but it seems probable that in the original low-intensity lamp the brilliancy of the positive crater was much lower than the values now attained. Later improvements in vertical trim lamps may have brought this value up to 150 cp/mm^2 and, in the low-intensity d-c reflecting arc a crater brilliancy of 175 cp/mm^2 is attained. This, as has been stated, is about the limit of brilliancy for the low-intensity d-c arc under stable operating conditions. The application of the high-intensity d-c arc to projection, about 1919 or 1920, removed this fixed limit to crater brilliancy which is an inherent characteristic of the low-intensity arc. High-intensity arcs are operated at crater brilliancies in excess of 800 cp/mm^2 and a recently developed super-high-intensity carbon for process projection can be operated at a brilliancy of 1200 cp/mm^2, an 8:1 improvement over the early types of projection arcs.

(*2*) *Light Quality*.—Improvements in quality of projection light have been along two lines, improved steadiness and improved color. The earliest projection lamps used solid carbons for both positive and negative electrodes. Due to a tendency for the arc stream to shift its position over the tip of the positive carbon, considerable unsteadiness in light output was experienced. This was reduced by the use of cored positive carbons. The effect of the core is to stabilize the arc stream at the center of the positive carbon face and thus improve the steadiness of burning. Further improvement in steadiness was effected by introducing a core in the negative carbon and later by substituting, for the plain negative carbon, equal to or near the diameter of the positive, a metal-coated negative carbon considerably smaller in diameter than the positive. This metal-coated negative carbon, called the "Silvertip" carbon, was introduced about 1916 or 1917. An improved metal-coated negative, the "Orotip" carbon, was developed several years later.

Steadiness of the a-c low-intensity arc was improved in 1917 by the introduction of certain rare-earth materials in the core of the carbons. This material, by its arc-supporting properties, greatly improves the steadiness of burning on alternating current. It has the further advantage of giving a snow-white projection light.

The neutral cored low-intensity arc, either a-c or d-c, gives a light of yellowish tint. The higher the crater temperature, the whiter the light produced, but at the maximum temperature attainable in the low-intensity arc the color composition on the basis of energy distribution is approximately 18 per cent violet and blue, 32 per cent

green and yellow, and 50 per cent orange and red. The adaptation of the high-intensity arc to projection about 1919 or 1920 made a marked improvement in the quality of light. The striking difference in color composition between the low-intensity and the high-intensity arc is shown in Fig. 6. It will be noted that the light from the high-intensity arc contains approximately equal proportions of all the primary colors. This quality of light proved much more pleasing for monochromatic pictures than the yellowish light from the low-intensity arc. With the introduction of color photography and the need

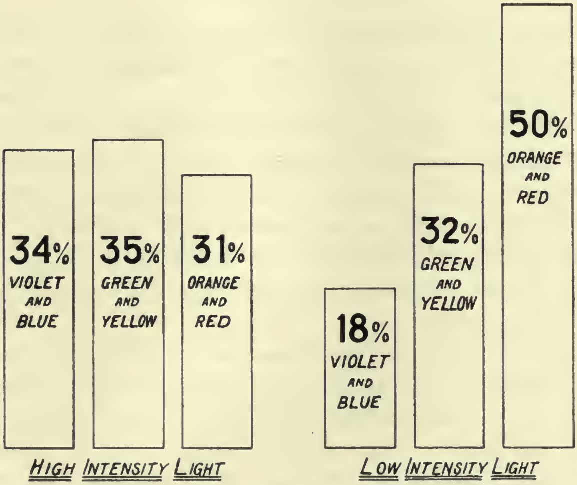

FIG. 6. Comparison of color composition of light from high-intensity and low-intensity carbon arcs.

for accurate color reproduction on the screen, the importance of snow-white projection light was increased, since all 35-mm film is processed for projection with light having approximately equal proportions of all the spectral colors.

Sixteen-mm color-film, on the other hand, is usually processed for projection with incandescent light, the type of light at present most frequently used in 16-mm projectors. This light is even yellower than that of the low-intensity arc. Since 16-mm projectors are often equipped with carbon arc lamps to permit their use before gatherings of considerable size, a new carbon trim, known as the "Pearlex" trim, was developed in 1937 especially for 16-mm projection. The

color composition of the light from this carbon, as now made, is proportioned to give accurate color reproduction with film processed for incandescent projection.

(3) *Volume of Screen Light.*—Although accurate records are not available, it seems probable that less than 200 lumens were projected upon the screen in the earlier motion picture theaters. This figure, as well as those on screen light which follow, are without shutter or film. When a shutter having 90-degree blades is used with no film, the figures will be reduced to one-half the values given. Further reduction, varying in amount, results from the density of the film being projected.

Improvements in carbons and in optical equipment of the old-style, vertical-trim projection lamps raised the available screen light to about 1600 lumens. The adaptation of the high-intensity arc to projection about 1919 further increased the available screen light to about 5700 lumens and was a major factor in making possible the marked increase in seating capacity of motion picture theaters which characterized that period in the history of the industry. Later improvements in the condenser system of the high-intensity lamps give almost 8000 screen lumens from a 13.6-mm high-intensity positive operating at 125 amperes.

A development of great importance to motion picture projection was the reflecting arc lamp, adapted to the d-c low-intensity arc about 1924 and to the high-intensity arc, as the "Hi-Low" lamp, about 1926 or 1927. The optical principle of the reflecting arc lamp, by greatly increasing the angle of light picked up from the arc and projected upon the screen, made it possible to obtain 2000 screen lumens from the d-c low-intensity arc, and subsequent improvements in carbons have increased this figure to 2400 screen lumens. At 32 amperes of arc current the d-c low-intensity reflecting arc gives 50 per cent more screen light than the condenser-type low-intensity arc operated at 50 amperes. The simplified high-intensity lamps, introduced in the early 30's, are also of the reflecting type. They have a light output of 4300 to 7200 screen lumens. The light output from the new low-wattage high-intensity lamps lies between the above range and the 2400 screen lumen output of the low-intensity reflecting lamp.

(4) *Efficiency of Light Production.*—Very striking improvement in the efficiency of screen light production has resulted from improvements in carbons and optical systems. The early low-intensity

lamps, using condenser lenses, gave, without shutter or film, less than 0.1 screen lumen per line watt, which was increased by various improvements in carbons and lamps to about 0.3 screen lumen per line watt. The condenser-type high-intensity lamps when introduced gave 0.4 screen lumen per watt, and subsequent improvement of the condenser lens system has brought this value up to 0.54 screen lumen per watt. The mirror arc lamp raised the efficiency of the d-c low-intensity arc to 0.65 screen lumen per watt, and increased efficiency of conversion equipment has made it possible to obtain 0.95 screen

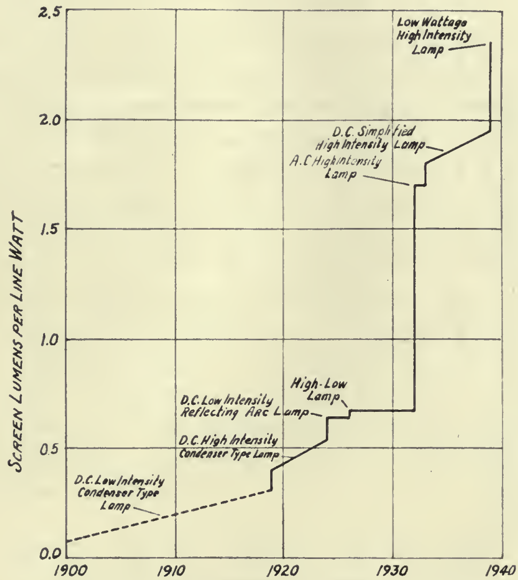

FIG. 7. Progress in efficiency of screen light production.

lumen per watt. In the "Hi-Low" lamp an efficiency of 0.67 screen lumen per watt is attained. The development of a-c high-intensity carbons and "Suprex" carbons for d-c operation in the early 30's, and the production of simplified high-intensity arc lamps for use with these small-diameter copper-coated carbons, increased the efficiency of light production to values from 1.7 to 1.95 screen lumens per watt. In 1939 a new negative carbon, known as "Orotip" *C*, was introduced, which permits the operation of the high-intensity arc at

lower voltage than was previously practicable. New d-c high-intensity lamps have been developed to use this negative and a "Suprex" positive with a power consumption at the arc of little more than 1 kw. A new a-c lamp of low arc wattage has also been developed in which the flicker sometimes found objectionable in the 60-cycle high-intensity arc is avoided by converting the power applied to the arc to 96 cycles per second. These new, low-wattage, high-intensity lamps give efficiencies as high as 2.35 screen lumens per line watt.

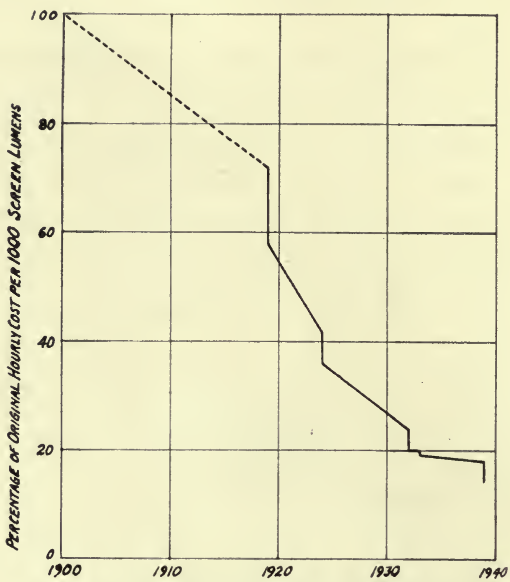

FIG. 8. Progress in economy of operation.

The ratio of improvement in screen light efficiency from the earliest low-intensity lamps to the latest high-intensity lamps is approximately 30:1. Fig. 7 presents a graphic picture of the progress made in efficiency of screen light production.

(5) *Economy of Operation.*—The economy of operation that has been realized from the improvement in carbons and lamps can best be illustrated by a comparison based on current carbon prices and a uniform rate for electric power. As a representative figure a power rate of 4¢ per kwh is assumed, given in the following tabulation:

Type of Lamp and Trim	*Cost per Hour per 1000 Screen Lumens* (per cent)
Early d-c low-intensity, condenser-type	100
Later d-c low-intensity, condenser-type	72
Early d-c high-intensity, condenser-type	58
Present d-c high-intensity, condenser-type	42
"Hi-Low," reflecting	36
Low-intensity, d-c, reflecting	24 to 32
A-c high-intensity, 60-cycle	19 to 21
D-c simplified high-intensity	18 to 19
New, low-wattage, high-intensity	14.5 to 18

Fig. 8 is a graphic presentation of the 7 to 1 gain in economy of operation represented by the data in the foregoing table.

When it is considered that the record of progress in the production and utilization of carbon arc projection light shows an 8:1 improvement in brilliancy of the source, a 30:1 improvement in the efficiency of screen light production, and a 40:1 improvement in the volume of light on the screen, together with marked improvement in color quality and steadiness, it must be recognized that projection lighting practice has kept fully abreast of progress in all other stages of the industry. A matter for further consideration is the fact that this tremendous technical advance in screen illumination has been accompanied by a 7:1 reduction in operating cost for an equal volume of light on the screen. There are few, if any, factors associated with the operation of motion picture theaters for which such a striking record of progress can be cited.

GASES FROM CARBON ARCS AND THEIR EFFECTS*

A. C. DOWNES**

Summary.—*This paper is a review of work done in the laboratories of National Carbon Company, Inc., the College of Medicine of the University of Nebraska, the School of Public Health of Harvard University, and the Department of Health of the City of Detroit on the products of combustion from carbon arcs used in the motion picture industry. Analyses of the gases coming from various lamps show that, even in the stacks, the only gas occurring in toxic concentration is nitrogen dioxide.*

The biological effects of undiluted stack gas from simplified high-intensity arcs upon experimental animals were only those due to the nitrogen dioxide.

The arc-ash fume when administered by intratracheal and subcutaneous routes in rabbits was found to be relatively inert.

Determination of nitrogen dioxide concentrations in poorly ventilated projection rooms failed to show any concentration more than about one-fifth that generally considered as allowable for exposure of several hours' duration, and therefore there is little or no hazard in these projection rooms.

Studies of ventilation under controlled conditions show that even with very low rates of both lamp house and room ventilation there is no danger of gases or fumes reaching concentrations which are toxic and that if sufficient ventilation is provided to produce comfortable working conditions there can not be any appreciable concentrations of nitrogen dioxide or arc-ash fumes in the booth.

From time to time in recent years, the question has been raised concerning the products of combustion of the carbon arc and their effect upon motion picture projectionists who work around arcs. Although many research workers of our company, including the author of this paper, have worked for years with carbon arcs under all kinds of operating conditions and under varying conditions of ventilation, no adverse effects have ever been noted. Naturally, therefore, it was not considered that there was any problem here.

Nevertheless, in view of these recent requests for information, it has seemed desirable for us to support some independent investigations along these lines, and to make some analyses in our own laboratories. The results of these investigations, as they have become

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** National Carbon Co., Cleveland, Ohio.

available, have been published in various scientific journals as will be noted throughout the text of this paper. The conclusions, inevitable in view of the long history of successful carbon arc usage, are most encouraging, and provide scientific justification for the continued good health of those of us who have worked in this field for so many years.

The literature on the carbon arc has many references to the gases evolved by arcs, the most frequently mentioned being nitrogen oxides, ozone, and carbon monoxide. A very careful investigation in our own laboratories has shown the presence of carbon dioxide and exceedingly small amounts of carbon monoxide, far below toxic range even in the undiluted stack gases; nitrogen oxides, but no ozone. Only the nitrogen oxides were found in toxic quantities and then only in the undiluted stack gases.[1]

Further study, using delicate spectrographic absorption methods, failed to show the presence of ozone,[2] and the statements in the literature which contradict this finding may well be due to the similarity of the chemical reactions of ozone and nitrogen oxides and the fact that their chemical separation is extremely difficult.

Tests on stack gases from a 65-ampere arc burning 8-mm copper-coated positive and 7-mm copper-coated negative non-rotating high-intensity carbons failed to show the presence of either hydrocyanic acid (HCN) or cyanogen (C_2N_2), and tests with ammoniacal silver nitrate solution indicated the absence of hydrogen sulfide, acetylene, phosphine, arsine, stibine, chlorine, and the other halogens.

Table I shows the analyses of the gases evolved from the carbon arcs commonly used in the motion picture industry. The table shows the amounts of these gases *in the lamp stack, and not in the room where the lamp was operated.* It is very important that this distinction be kept in mind in the analysis of any data bearing on this question of gases from carbon arcs.

The gas given off in largest amount in motion picture arcs is carbon dioxide, entirely innocuous in far higher concentrations than found in the gases from any arc. Only one investigator has apparently been able to detect any carbon monoxide in arc gases and even then rarely and in quantities even in the stack gas far less than the concentrations generally considered safe for exposures of several hours' duration.[3]

The only other gas produced in measurable quantities in carbon arc lamps is the so-called "nitrogen oxides." This is the only one

TABLE I

Analyses of Gases from Carbon Arcs Commonly Used in the Motion Picture Industry

Type of Arc and Carbons					Current, Amperes	Voltage, Volts	Heat Liberated at Arc, Btu per Min.	Air Flow through Lamp, Cu Ft per Min.	Carbon Dioxide CO_2 (Per Cent)	Carbon Monoxide, CO Ppm*	Nitrogen Peroxide, NO_2 Ppm*
Low-intensity	d-c	13-mm	Pos.	Plain	30	55	108	5.1	0.48	..	270
		10-mm	Neg.	Plain							
White-flame	d-c**	1/2-mm	Pos.	Plain	35	40	80**	4.9	0.37	..	190
		1/2-mm	Neg	Plain							
Suprex	d-c	7-mm	Pos.	C.C.	50	35	114	3.8–9.4	0.28	..	126–205
		6-mm	Neg.	C.C.							
Suprex	d-c	8-mm	Pos.	C.C	65	35	149	6.8–7.4	0.30	40	125–143
		7-mm	Neg.	C.C.							
High-intensity	d-c	13.6-mm	Pos.	Plain	125	66	540	39	0.21	..	270
		7/16-mm	Neg.	C.C.							
High-intensity	d-c	16-mm	Pos.	Plain	150	74	726	40	0.30	20	305
		7/16-mm	Neg.	C.C.							

* Ppm—Parts or volumes of gas per million parts or volumes of air.

** This type is usually burned with two arcs in series in the same lamp house. This value is for only one arc.

found in amounts which could be considered toxic, and then only in the undiluted stack gases. There are several oxides of nitrogen, but the only one directly formed by the action of the carbon arc in air is nitric oxide (NO). This gas, upon contact with the moisture and oxygen of the air, is immediately converted to nitrogen dioxide or nitrogen peroxide (NO_2, N_2O_4), and it is the concentrations of this gas, as NO_2, that are given in the table.

For prolonged exposure without hazard to human beings, Henderson and Haggard[3] give a maximum concentration of 39 parts per million of nitrogen dioxide (NO_2) and the stack gases from the arcs given in Table I all contain more than this amount. However, an

TABLE II

Chemical Composition of Ash from the Arc

Substance	Flue Condensate (Per Cent)	Lamp House Condensate (Per Cent)
Silicon dioxide	1.79	1.21
Rare earth oxides	65.70	71.80
Ferric oxide	2.26	1.46
Calcium oxide	0.53	0.20
Potassium oxide	2.26	2.38
Sulfur trioxide	2.35	2.98
Phosphorus pentoxide	0.17	0.15
Fluorine*	10.65*	11.31*
Boric anhydride	0.50	0.60

* Combined with the rare earths as the very insoluble fluorides.

arc would have to be burned a very long time, even in a small room with practically no ventilation, before the room air would reach any such concentration. Moreover, in making the determinations reported in Table I, no ventilation of the lamp houses was provided, other than that induced by the heat liberated at the arc, in order to provide the highest possible concentrations of the various gases in the stacks so that the chemical determinations would be as accurate as possible.

Generally speaking, the amount of nitrogen oxides increases with the arc wattage, while at the same wattage a low-intensity arc will probably produce more than a flame or a high-intensity arc. With a given arc, less nitrogen oxide is produced with a properly regulated, steady arc than with an unsteady one.

In addition to the true gases produced by the operation of arcs in air, the volatilization in the arc of the rare earth metal compounds of the core materials of flame and high-intensity arcs produces a white smoke or fume which is made up of very small particles not more than 0.2 micron in size.[4] An average chemical analysis of these particles is given in Table II.[5]

Studies of the biological effects on experimental animals of the arc gases and fumes together, of the arc gases alone after removal of the smoke by filtration, of pure nitrogen oxides produced from nitric acid, and of the condensed ash from the fume, have been made by MacQuiddy, Tollman, LaTowsky, Bayliss, and Schonberger at the College of Medicine of the University of Nebraska.[5,6,7,8,9]

In their first experiments groups of albino rats and guinea pigs were exposed to the undiluted, unfiltered, complete stack gases from a non-rotating, high-intensity arc burning 7-mm × 12-inch-copper-coated positive and 6-mm × 9-inch copper-coated negative carbon electrodes at 40–55 amperes and 28–36 volts direct current. One group of animals was exposed for one hour per day, six days per week for a maximum of ten months; another group for four hours per day, six days per week, for a maximum of eight months; and a third control group was kept in the same room but not exposed to the arc gases at all. It was found necessary to cool the arc stack gases but otherwise they were just as they came from the arc.

The flow of air and gases through the lamp, stack, and animal exposure chamber attached was at the rate of only 3.8 to 9.4 cubic-feet per minute, the average of 17 weekly flow tests being 6.1 cubic-feet per minute. The average content of nitrogen oxides (NO_2) was 160 parts per million, varying from 100 to 205 ppm. The carbon dioxide content of the gas was from 0.245 per cent to 0.277 per cent. No carbon monoxide and no sulfur dioxide were found, and the authors, like ourselves, were unable to confirm the statements in the literature that ozone was present.[5]

In considering the conclusions resulting from this work it must be remembered that the exposures were in the undiluted stack gases with concentrations of nitrogen oxides more than four times as high as Henderson and Haggard's[3] recommended concentration of 39 parts per million for safe prolonged exposure.

The following are the exact words of the conclusions of MacQuiddy *et al.* as a result of this work.[6]

"(*1*) The undiluted gross fumes arising from an electric carbon

arc are toxic to mice, rats, guinea pigs, rabbits, and cats, when inhaled under the conditions of exposure described. The pathology indicates that the oxides of nitrogen produced these changes.

"(*2*) Undiluted gross arc fumes when inhaled for 1 hour a day for as long as 10 months produced no pathological changes in the tissues or blood morphology (structural characteristics) of guinea pigs. Under the same conditions albino rats died in a period of 11 to 32 weeks' exposure with acute, sub-acute, and chronic lung inflammations.

"(*3*) Undiluted gross arc fumes when inhaled for 4 hours a day caused the death of 90 per cent of the guinea pigs exposed in from 2 to 7 months. At a variable time after exposure began animals showed a gradual marked weight loss. They showed an increase in the leucocyte (white blood cell) count attributed to a polymorphonuclear leucocytosis,* increased non-protein nitrogen of the blood, and a decreased CO_2 combining power of the blood plasma. Tissue changes consisted of inflammatory changes in the upper and lower respiratory tracts, and fatty change in the livers.

"(*4*) All the albino rats exposed 4 hours a day to the undiluted gross arc fumes died in from 1 to 16 weeks with marked inflammatory changes in the lungs."

MacQuiddy *et al.* have run two similar series of animal experiments, one using the gases from the same arc from which the white fume was removed by filtration, and the other similar concentrations of nitrogen oxides produced by the action of nitric acid on copper. Their conclusions from this work are:[9]

"First, the result of the inhalation of the carbon arc fumes filtered is very similar to the unfiltered arc fumes with the exception that the lungs do not show the number of dust particles in them that the lungs in the unfiltered arc fumes show.

"Second, the results of the inhalation of pure chemically made nitrogen oxides were very similar to the result obtained from the filtered arc fumes. There being understood that the pure nitrogen oxides were used in as nearly the same concentration as the nitrogen oxides present in the concentrated arc fumes."

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* Polymorphonuclear leucocytosis—the polymorphonuclear is the predominating form of the white blood corpuscles and the term means an increase in the white blood corpuscle count due to the increase in this one dominant form of white blood cell.

MacQuiddy and his associates attempted to determine the effects of the inhalation of the arc ash alone without the concomitant nitrogen oxides and carbon dioxide by exposing guinea pigs to the high-intensity arc ash collected from the lamp and stack, and kept in suspension in the exposure chamber by a fan.[7] The resulting concentration of ash particles in the 2.3-cubic-foot chamber was enormous, varying from 12.8 to 24.7 milligrams per cubic-foot (451.8 to 871.9 mg. per cu.-m.), which correspond to something between 192 million and 864 million particles per cubic-foot. The very wide variation between these values is due to the uncertainty as to the size of the ash particles due to the agglomeration which occurs when the arc fume condenses on surfaces. Drinker and Snell[4] found only 55.4 million particles about 0.2 micron in size per cubic-foot* at the image card of a non-rotating high-intensity arc lamp even with the insufficient stack flow of 7 cubic-feet per minute. It is therefore evident that the inhalation experiments of MacQuiddy and his co-workers were far more severe than any probable projection booth exposure. After exposures of 3 hours per day, 6 days per week, for 6 months, and observations of some of the animals for 9 months afterward, no discernible changes could be found in the animals. The authors then raised the point that these experiments might not be directly applicable because of the fact that the ash particles were agglomerates and not of the size (0.2 micron) found in the arc fumes. They point out, however, that particles as small as 0.2 micron are not likely to be retained by the lung, and van Wijk and Patterson[10] found that only 27.8 per cent of the 0.2-micron particles are removed by breathing dust-laden air.

MacQuiddy and his associates also studied the effects of high-intensity arc and other arc ashes, using intraperitoneal (within the abdominal cavity) injection into rats and intratracheal insufflation (blowing into the windpipe) and subcutaneous injection in rabbits in comparison with several dusts of known effects. The technic of the intraperitoneal and intratracheal injections of dusts has been developed by physicians in order to obtain in a relatively very short time indications of the probable effects when human beings are exposed to air bearing such dusts in suspension. Generally speaking, results from intraperitoneal and intratracheal injections of dusts are

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* The New York State Code for Rock Drilling permits a concentration of 100 million particles per cubic-foot if the rock contains less than 10 per cent free silica. The arc ash has a silica content which is much less than this.

obtained in a few weeks or months which would take times of the order of 20 years by breathing dust-laden air. In considering results of these injection experiments one must always bear in mind that they are necessarily conducted on small animals such as white rats, guinea pigs, and rabbits. It is reasonable to suppose that reactions in still larger animals, man, for example, will be less violent than in rabbits.

The conclusions of MacQuiddy *et al.* from this work are:[7]

"(*1*) The reaction to intraperitoneally injected silica, hematite, carbon, and talc in white rats corresponds to the reported results in guinea pigs.

"(*2*) Tissue reaction in the peritoneal cavity of the albino rat was found generally to be more violent than the reaction either in the lung or the subcutaneous tissues of the rabbit.

"(*3*) Some of the high-intensity carbon arc ashes appear to cause mildly proliferative reactions when injected intraperitoneally in the albino rat. The reactions to these arc dusts when administered by intratracheal and subcutaneous routes in rabbits are relatively inert.

"(*4*) The rare earth metal salts, some of the carbon arc ashes, calcium phosphate, cupric oxide, and calcium fluoride appear to be essentially inert."

The amounts of nitrogen oxides, other gases, and ash fume from arc carbon cores and their possible effects in concentrations found in the stacks from projection lamps are of great fundamental interest, but, after all, the important facts to determine are the effects that may be produced in the projection rooms themselves, some of which are much too small and lacking in adequate ventilation. Calculations show that there is little probability of dangerous concentrations of nitrogen oxides being reached in even small motion picture projection booths, but calculations are seldom as satisfactory as actual determinations.

Fortunately we have the results of a very complete survey made by the Department of Health of the City of Detroit, Mich., of 147 theaters in that city, which are reported in a paper read by William G. Frederick[11] before the American Conference on Occupational Disease and Industrial Hygiene in 1939 at Cleveland. It seems very probable that the conditions found in the Detroit theaters, which embraced all sizes, can be considered typical of the picture houses of the entire country, so that Frederick's paper is of significant value to the entire industry.

The projection booths included in this investigation varied in size from 200 to almost 8000 cubic-feet and 105 of the 147 had volumes of over 1000 cubic-feet. Seventy-two had low-intensity lamps (defined by Frederick as less than 40 amperes), 37 had high-low lamps (defined as 40–85 amperes), 38 had high-intensity lamps (defined as over 85 amperes), and 2 had arc type spot and special effect lamps only.

TABLE III

Showing NO_2 Concentrations Found

Number Theaters	Amperage	Stack Sample Actual Ppm	Stack Sample Av. Ppm	Booth Sample Actual Ppm	Booth Sample Av. Ppm
2	15	23, 23	23	1.6, 0	0.8
3	18	202, 114	158	3.1, 3.1, 6.2, 6.2, 7.8, 4.7	5.2
14	25	None taken		1.6, 2.2, 3.2, 2.2	2.3
16	25	24, 46	35	3.2, 0	0.6
21	28	238, 266	252	2.6, 1.6	2.1
25	30	113, 119	116	3.1, 4.6, 3.1	3.6
28	32	123, 123	123	0, 0	0
29	32	134, 168	151	2.3, 3.1	2.7
30	35	88, 266	177	1.6, 3.1, 0	1.6
31	40	163, 7	85	1.6, 0	0.8
32	40	24, 46	35	3.1, 0.7	1.9
33	45	79, 101	90	1.6, 0	0.8
34	45	56, 46	51	0, 0	0
35	45	38, 22	30	2.4, 0	1.2
36	55	24, 58	41	0, 0, 0	0
37	60	25, 23	24	0, 0	0
38	65	None taken		0, 0	0
39	65	39, 39	39	3.1, 3.13, 3.1, 6.2, 3.1	3.9
40	75	363, 321	342	0, 0	0
41	85	26, 22	24	0, 0, 3.0, 0, 0, 0	0.5
42	120	None taken		0, 0, 0, 0	0
43	120	9, 1	5	3.2, 0	1.6
44	120	None taken		3.2, 1.6, 0, 0, 0, 0	0.8
45	130	46	46	0, 0, 0	0

Frederick describes and justly criticizes some of the ventilating systems used. However, we are primarily interested in his findings with regard to air contamination in the booth by gases from the arcs, with respect to which he has divided the booths into three classes, on the basis of fume odor. Class *1* (53 booths) had satisfactory ventilating devices and no fume odor; class *2* (47 booths) had questionable ventilating devices and a slight fume odor; class *3* (47 booths) had definite fume odor.

Careful analyses of air from the worst booths, those of class *3*, showed that in no case was the nitrogen oxide concentration more than 8 parts per million, approximately one-fifth of the allowable concentration of 39 ppm for prolonged exposure.[3] Fifteen booths showed no measurable quantity of this gas, 32 less than 2 ppm, 41 less than 5 ppm, and only 3 (6.4 per cent) had over 5 ppm. Table III gives the detailed results of these Detroit analyses.

It was quite properly concluded that the low concentrations of nitrogen oxides found in even the poorly ventilated booths of class *3* precluded any possibility of finding appreciable amounts of the gas in the better ventilated booths of classes *1* and *2*. Frederick further states that no evidence of carbon monoxide poisoning was discovered among projectionists although no actual analyses for this gas were made. His conclusions are as follows:

"The results of this fact finding study of the motion picture industry in Detroit indicate that no alarming health exposures are prevalent. The principal toxic agent to which workers are exposed is 'nitrous fumes.' Careful measurement of this exposure indicates it to be below the level usually considered harmful. Projection booths should be provided with adequate sanitary facilities, a suitable fresh-air inlet, and a positive pressure exhaust fan at the top of the fire stack. The present building code of the City of Detroit provides for these features. The study reveals the industrial hygiene of the motion picture industry in Detroit in general to be good."[11]

Unfortunately we have no data on concentrations of arc ash particles in motion picture projection booths similar to Frederick's nitrogen oxide determinations. However, Drinker and Snell[4] of the Harvard School of Public Health have determined arc ash particle concentrations in a 3000 cubic-foot air-conditioned room in which the ventilation could be varied. A non-rotating high-intensity lamp with a ventilating flue was installed in this room, and connected so that the rate of air flow through the lamp house could be varied and controlled. This lamp was operated at about 62 amperes and 43 volts with 8-mm × 12-inch copper-coated positive and 7-mm × 9-inch copper-coated negative carbons.

Operating with a controlled variety of ventilating conditions, Drinker and Snell[4] determined the numbers of ash particles at the image card on the lamp, at the operator's position, and in the room away from the lamp, before and after the lamp had been in operation for 30 minutes. Table IV gives their results with air flows of 7, 15,

TABLE IV[4]

Concentrations of NO_2, CO, CO_2, and Dust in Room and Flue at Various Flue Ventilation Rates

Flue Ventilation, Cfm	Room Ventilation, Cfm	NO_2: Arc Image Card, Ppm	NO_2: Room, Ppm	NO_2: Flue, Ppm	CO in Flue, Ppm	CO_2 in Flue, Per Cent	Dust Counts: Arc Image Card, Millions/Cu Ft*	Dust Counts: Operator's Position, Millions/Cu Ft*	Dust Counts: Room Before, Millions/Cu Ft*	Dust Counts: Room after 30 Minutes, Millions/Cu Ft*
50	1000	. .	0.00	38.0	<50	0.11	0.57	0.57	1.02	0.74
15	1000	2.6	0.46	103.0	<50	0.17	4.80	2.90	0.29	1.60
7	1000	66.0	1.04	180.0	<100	0.28	55.40	16.70	2.11	11.50

* Taken by Bausch & Lomb counter—results are higher than the conventional impinger apparatus would show because, as stated previously, the Bausch & Lomb technic is more sensitive than the impinger for the collection and enumeration of very fine suspensions.

and 50 cubic-feet per minute through the lamp house and 1000 cfm through the room. It is evident from the table that the particle count, even at only 7 cfm through the lamp, never approaches the New York State Code for Rock Drilling figure of 100 million particles per cubic-foot previously quoted, either near the lamp or elsewhere in the room. Table IV also shows the nitrogen oxide concentrations at the same locations and consideration of these together with the particle counts indicates that it would be impossible for the arc ash fume to reach any concentration even approaching a disagreeable condition.

The amounts of less than 50 and less than 100 parts per million of carbon monoxide in the stack gases shown in Table IV are within the concentrations specified by Henderson and Haggard[3] for safe exposure for several hours. Moreover, Drinker and Snell explain these carbon monoxide values as follows:

"..... carbon monoxide was followed by the Mine Safety Appliances Company's indicator. MacQuiddy *et al.*[6] point out that this latter device is inaccurate in the presence of nitrogen oxides and that actual concentrations are less than those shown by the indicator, the accuracy of which in our case was about 50 ppm for pure carbon monoxide."

Their values are absolute maxima which even themselves are safe for several hours' carbon monoxide exposure direct in the stack gases.

Drinker and Snell show that with a flow of 12 to 15 cubic-feet of air per minute through the lamp house there is no sensible escape of nitrogen oxides or other substances into the room; therefore if this minimum requirement is met there can be no question of any industrial hazard in a motion picture booth and, as a matter of fact, there probably is no hazard under much worse conditions than this, as shown by Frederick's survey in Detroit.[11]

In spite of the fact that there is probably no serious hazard in even a very poorly ventilated booth, the necessity and desirability of adequate ventilation should really rest on grounds entirely separate and apart from the gas and fume consideration. The proper approach to the solution of projection booth ventilation should be from the general standpoint of providing reasonably comfortable working conditions for the projectionist. If this be done, and even if the draft through the lamp house should be inadequate completely to eliminate the arc gases from the room, they can not possibly approach an objectionable concentration in the booth.[4] Table V shows the

effect of the draft through the lamp house on the concentration of nitrogen oxides in the booth, and the amount of booth ventilation which must be provided to give temperature rises of 5°, 10°, 15°, and 20°F in the room with a simplified high-intensity arc.

Table V shows very clearly the great effect of the rate of air flow through the lamp house on the air required for adequate booth ventilation. The amount of air required depends only on the heat liberated by the arc and if this is eliminated by ventilation there is no problem of gas removal.

TABLE V[4]

Summary of Room and Flue Ventilation Requirements

Temperature Rise in Room, °F	Flue Ventilation, Cfm	Room Ventilation, Two Lamps (Alternating) at 187 Btu/Min. Cfm	Calculated NO_2 in Room, Ppm
5	0	2130	0.87
5	15	1810	0.26
5	50	1300	0
5	100	920	0
10	0	1090	1.76
10	15	905	0.51
10	50	650	0
10	100	460	0
15	0	727	2.64
15	15	603	0.77
15	50	433	0
15	100	307	0
20	0	545	3.53
20	15	452	1.01
20	50	325	0
20	100	230	0

In regard to the possibility of harm to the operator from presence of toxic fumes in the booth, it should be remembered that for many years the concentration of 39 parts per million of nitrogen dioxide has been considered safe for continuous exposure.[3] Table V shows that with no flue ventilation with 20° rise in room temperature and a room ventilation in the booth of only 545 cubic-feet per minute, less than one-tenth of the permissible limit of nitrogen dioxide would be present. If there is a ventilation of only 15 cubic-feet per minute in the lamp flue and a temperature rise of 5° in the booth, only 0.26 part per million of nitrogen dioxide will be present in the room air, that is, $^1/_{150}$ of the recognized safe limit for continued exposure.

Table VI gives the ventilation necessary to hold the temperature

TABLE VI[4]

Ventilation Required to Hold Temperature Rise in Projection Booths to 5° F

Type of Arc and Carbons		Positive		Negative		Amperes	Volts	Heat Liberated at Arc, Btu per Min.	Air Flow through Lamp House, Cfm	Heat Passing out Lamp Stacks (Per Cent)	Btu per Min. in Room	Air Flow through Room for Temp. Rise of 5°F, Cfm
Low-intensity	d-c	12-mm	Plain	8-mm	Plain	30	55	108*	15	11.0	96.2	1105
									50	40.5	64.3	740
									100	57.8	45.6	525
Suprex type	d-c	7-mm	C.C.	6-mm	C.C.	50	35	114*	15	11.0	101	1160
									50	40.5	67.8	780
									100	57.8	48.1	555
Suprex type	d-c	8-mm	C.C.	7-mm	C.C.	65	35	149*	15	11.0	132.6	1525
									50	40.5	88.7	1020
									100	57.8	62.9	725
High-intensity	d-c	13.6-mm	Plain	7/16-"	C.C.	125	66	540*	50	40.5	321	3690
									100	57.8	228	2620
High-intensity	d-c	16-mm	Plain	7/16-"	C.C.	150	74	726*	50	40.5	432	4970
									100	57.8	307	3530

* This is based on one lamp running continuously and a second lamp running 9 minutes in each hour to allow for change-overs.

rise to 5°F in a projection room with 15, 50, and 100 cubic-feet per minute through the lamp house for the common types of arc used in projection. In calculating the air required the losses through the walls of the booth were considered negligible. These values are for a 5°F rise only but the ventilation for any other temperature rise can be easily calculated. For example, a rise of 10°F will require only one-half as much air through the booth as for 5°F rise.

Table VI shows very plainly that the amounts of air required to give safe, comfortable working conditions (a 5°F temperature rise in the booth) are not excessive and the results that will be obtained should appeal to both projectionists and theater owners.

Studies of ventilation under controlled conditions show that even with very low rates of both lamp house and room ventilation there is no danger of gases or fumes reaching concentrations which are toxic, and that if sufficient ventilation is provided to give comfortable working conditions there can be no appreciable concentrations of nitrogen dioxide or arc ash fumes in the booth.

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DISCUSSION

MR. FRANK: I suggest that it might be a good idea to consider reprinting in our JOURNAL the paper on the survey of the Detroit theaters. It would be of interest to all of us, although perhaps the most important facts have already been given us by Mr. Downes.

MR. DOWNES: A very considerable part of that paper is concerned with sanitary conditions of booths which no doubt would be of interest here, but I have abstracted very carefully the part of the paper dealing with any possible hazards and have quoted verbatim the important data and conclusions.

MR. KELLOGG: Nothing has been said about the fact that the psychological effects of fumes that one can smell may be much more serious than the actual physical effects. Human beings do have imagination, and imagination can cause serious physical effects. It is not quite fair to ask a man to work under conditions where you have to prove to him by tests on guinea pigs that those conditions are entirely healthful. The story of the tests on guinea pigs and white rats will go a certain way toward removing the fear of persons having their health affected because they smell fumes. But we must not get the idea that that is all that is necessary. The results of the tests are very interesting and significant, but in my estimation it is still important to provide such good ventilation that no one working in the booth will ever begin to worry about whether the fumes are harmful or not.

MR. DOWNES: In replying to Mr. Kellogg's question I wish to emphasize the several statements in the paper that the guinea pigs and rats were exposed to undiluted stack gases with a very low rate of air flow through the lamps to obtain high enough concentrations of nitrous oxides to have definitely positive effects on the animals, and that these concentrations were many times those found in the survey of projection booths in Detroit.

We have pointed out in the paper that ventilation should be provided in projection rooms, and that the amount of ventilation should be determined by the volume of air necessary to provide bodily comfort to the projectionists, and not upon the presence or absence of fumes. If this basis be used, there can be absolutely no concentrations of fumes in such projection rooms which would be noticeable even to the most delicate sense of smell. Under such conditions the psychological effects, if any, of smelling disagreeable odors would be entirely eliminated so far as fumes from the lamps are concerned.

MR. RICHARDSON: I have always advocated good conditions in projection rooms, but sometimes I have wondered whether we have not been little over-nervous of the gas fumes. In the old days we worked in rooms that had no special ventilation. The fumes from the arc all went all over the room. I worked under such conditions for four years, and yet am pretty healthy.

If our present projection rooms are well ventilated, as they should be, and the lamp house is piped to the open air outside the theater, I can not see any danger to anyone who has anything like normal health.

MR. DOWNES: I was very much impressed by the fact that the pictures of early projection rooms shown earlier by Mr. Richardson showed a complete absence of ventilation of lamp houses but Mr. William Reed who began operating in 1896 is here this afternoon and is still operating.

AUDIENCE NOISE AS A LIMITATION TO THE PERMISSIBLE VOLUME RANGE OF DIALOG IN SOUND MOTION PICTURES*

W. A. MUELLER**

Summary.—*A series of noise measurements were made in theaters to determine the cause of low intelligibility of dialog recordings of wide volume range. Audience noise level was found to be a serious restriction, because it averages 8 db louder than film noise level and reduces the useful volume range by that amount. Audience noise is an extremely variable factor, as measurements made in the same theater showed it to be as low as the film noise in one instance and later to rise 14 db above this value. To secure good intelligibility, the volume range of the dialog must be compressed so that the softest-spoken words never are so low in level as to be seriously masked by audience noise.*

Sound engineers have been striving since the introduction of sound in motion pictures to extend the volume range of recording systems for the purpose of enhancing the dramatic and comedy possibilities of the sound and affording the actor and producer a better medium for presenting their story.

Constant research and development by sound equipment manufacturers and motion picture studio engineers have resulted in the invention of noise reduction, quieter film stocks, better developing and printing machines, improved photoelectric cells, vacuum tubes, and other items too numerous to mention, each of which has contributed to a reduction of the reproduced noise level of the recording, and therefore to an increase in volume range.

This fine work has resulted in an overall linear recording system with a greatly extended volume range, and scenes heretofore lifeless and flat can now be presented with greater emotion and realism, and as a consequence have greater dramatic value. The increased dramatic value of the wide-volume-range recordings was quickly realized by the actor and the director, and soon many scenes were being staged to take advantage of it.

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** Warner Bros. Pictures, Inc., Burbank, Calif.

When pictures recorded with this extended volume range were first released, sound engineers and theater managers complained that these recordings were hard to understand. This factor of low intelligibility was not noticeable in studio review rooms and was not particularly bad in empty theaters; but in a theater with an audience present there was considerable dialog that was hard to understand. This was not only true from scene to scene, but was even more disturbing in the loss of intelligibility from word to word.

Some words uttered by the characters on the screen could be clearly understood, while others seemed to be absorbed and entirely removed before they reached the audience. In effect, the audience was acting as a selective filter which suppressed certain words and permitted others to pass through to the listener. This was especially pronounced at the end of the sentences where many actors have a tendency to lower their voices and trail off into almost inaudible sound.

In some theaters it was found that the intelligibility could be improved by raising the normal fader settings; but when this was done the louder sequences in the picture, particularly the opening title music, overloaded the amplifier equipment. In other words, the amplifier capacity of these theater equipments was not adequate to reproduce pictures with a wide volume range. In other theaters where adequate power was available there was considerable audience annoyance because the high-level portion of the dialog became explosive and disagreeable and the actors sounded as if they were "barking" at one another.[1] The immediate remedy was to raise and lower the sound level manually, effectively reducing the volume range. While this necessary compression of the volume range was in direct contradiction to the premises on which the new recording system had been developed, there was no denying that the manually compressed dialog recordings had higher intelligibility and were less "explosive" in the theater than those of wider volume range.

Since this loss of intelligibility was not apparent in studio reviewing rooms, and was not definitely pronounced in empty theaters, it must have been due to the theater audience and was undoubtedly caused by the masking effect of audience noise. That is, the audience noise was sufficiently greater in intensity than certain syllables or words of the dialog so as to make them unintelligible, or even to eliminate them entirely. In other cases, entire scenes and sequences which were spoken very softly were so badly masked by audience noise as to

cause complete lack of intelligibility and, consequently, the loss of the story sense of the production.

That the above explanation was true was not apparent even to the most experienced listener, and it was decided to make a series of noise tests to confirm this theory. Table I shows a series of noise measurements taken in several theaters and studio review rooms, for this purpose. These measurements were made with a General Radio Type *759* Sound Level Meter, using the weighting networks as indicated. This instrument is calibrated on the basis of a zero reference level of 10^{-16} watt per sq-cm. The figure shown for each theater represents the average of a large number of readings taken at different positions in the auditorium. Measurements of the audience noise level were taken when silent trailers were being run or in a silent period between different portions of the show. A silent period of 30 seconds was secured by delaying the start of the next feature, keeping the house lights and the screen dark.

It should be noted that the noise level of the empty theaters is quite uniform, averaging +25 db. Also, the noise level is increased to +30 db when the ventilators are turned on. The noise caused by the audience, however, is surprisingly high, averaging +42 db and masking all other types of noise. Audience noise also is subject to a wide variation, rising to as high as +48 db at the end of the main feature when many people were leaving and entering. A measurement of +32 db was also obtained during a very dramatic sequence when the audience was unusually quiet. The figure of +42 db was the average of many such readings.

The average level for dialog was +65 db, and loud music reached a level of +74 db. The loud music consisted of opening and closing title music and musical numbers, which are the loudest portions of any sound film and are recorded at 100 per cent modulation.

These measurements show that a range of only 32 db is available between the loudest music reproduced in these theaters and the level of the audience noise. It has been found that the dialog should be at least 6 db above any noise level in order to be clearly understood. This requirement would mean that the absolute minimum level of the dialog should be +48 db. Since the maximum level in the auditorium which is attained at 100 per cent modulation of the film was +74 db, the usable volume range remaining is only 26 db.

This means that dialog which can be clearly understood in a theater must never fall more than 26 db below 100 per cent modulation of

the recording medium, as any words or scenes which fall below this level will be masked by audience noise and not understood. The only way that this permissible volume range for dialog can be increased is to reduce the noise level in the theater or to increase the maximum loudness that can be tolerated on dialog. The audience noise level is very difficult to control and since psychological and physiological factors determine the annoyance caused by loud sounds, it appears that there is no easy way to extend this volume range.

Inspection of Table I shows also why the intelligibility of the high-volume-range recordings was not impaired in the studio review rooms where, without an audience, the noise level is at least 15 db below

TABLE I

Theater Sound Level Measurements

Theater	Quiet	Ventilators on	Audience Noise	Dialog Level	Loud Music
	40 Db Weighting Network			70 Db Weight Network	
Huntington Park	+28.8 db	+30.5 db	+43 db	+64 db	+74 db
Granada	+23.7	+26.8	+41	+69	+73
Downtown	+25.2	+34.5	+43	+66	+74
California	+25.6	+29.2	+38	+60	+72
Mission	+24.3	+32.4	+44	+65	+72
San Pedro	+25.0	+28.3	+40	+62	+72
Hollywood	+24.0	+28.1	+44	+62	+76
Averages	+25.1 db	+30.0 db	+42 db	+65 db	+74 db
Studio Review Room No. 4		+26 db	...	+66 db	+76 db
Studio Review Room No. 5		+24	...	+65	+75

Zero Power Level = 10^{-16} watt per sq-cm.

that of the average theater. This results in a usable volume range of 40 db, permitting the low-level syllables, words, or scenes, which are lost in a theater, to be clearly understood.

Several pictures were recorded and released with dialog of reduced volume range, based on the above analysis (see Table I), and excellent results were immediately obtained. Complaints on lack of intelligibility ceased, and the reports showed that cueing of the sound level of these pictures, in the theaters, was no longer necessary or being practiced. As a result the procedure was adopted universally for all Warner Bros.' releases, and at present the volume range of the *dialog* in our pictures is limited to 25 db. This restriction of volume range is secured by means of electronic compressers which are installed in all recording channels.

While it has been found impossible to use the full volume range of the recording system for dialog because of audience noise, the present dialog recordings are still of greater range than those formerly released, and many fine comments on their naturalness and dramatic qualities have been received.

It should be emphasized that only the volume range of dialog has been under consideration, and our conclusion is that there should not be more than 25 db difference between the softest whisper and the

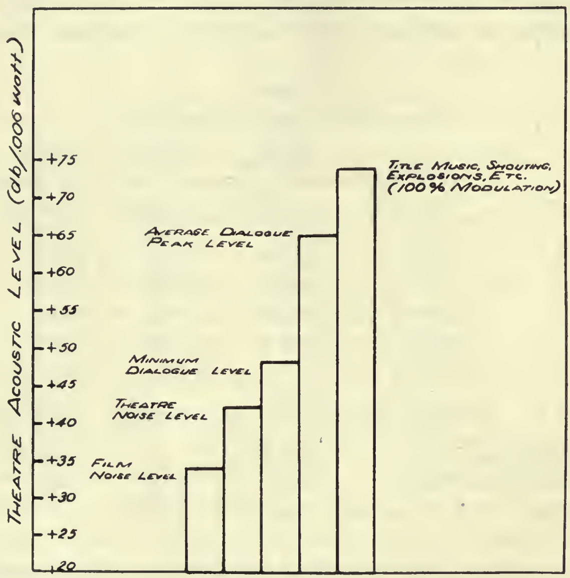

FIG. 1. Volume characteristics of Warner Bros.' recordings.

loudest spoken word. The relation between the loudness of average dialog and opening or closing title music or musical numbers, has not been discussed but our measurements show that for Warner Bros.' pictures, it averages about 9 db (see Fig. 1). The producers and studio executives would like this figure increased, but so many complaints are received that the music is too loud whenever this is done, that a compromise has been made on the above figure. Many of these complaints come from exhibitors with old or obsolete sound equipment, which overloads on the high-level passages. Until these equip-

ments are replaced, the dramatic effect desired by the producers can not be put into motion pictures.

There is also another serious limitation to the most dramatic use of sound in motion pictures, and that is because even our present recording systems do not have sufficient volume range to accommodate loud explosions, battle scenes, earthquakes, and so on. Many theaters with modern equipment cue these scenes by raising the level as much as 10 or 12 db, resulting in a much more dramatic and effective presentation. In order to accommodate these sounds the level difference between normal dialog and 100 per cent modulation should be increased from 9 db to 20 db. The acoustic level of the loudest sounds could then rise to +84 db instead of +74 db as at present. The sounds which would rise to this level would be sound effects only, as experience shows that audiences object strenuously to music which rises even 2 or 3 db above the loudness of present title music, *i. e.*, +74 db, as measured in the auditorium of the theater. The lowest dialog should not fall below +48 db or 6 db above audience noise, and it should be compressed into a 25-db range. The film noise should be 8 db below the audience noise, or at a +34-db level, so that it does not contribute materially to the noise level of the theater.

The volume range of such a recording system would be 50 db, and this should be secured from prints after a number of runnings in theaters, and not as they come from the release laboratory. This would be a 10-db improvement over the volume range of our present recording system, which averages 40 db, based on the noise level of prints after numerous runnings in theaters. Such a new recording system would meet every demand of the producers and exhibitors, but recordings made in this manner could not be reproduced on the obsolete, under-powered equipment now in many theaters. Studio sound engineers and equipment manufacturers are diligently working to perfect such a system, which when developed will further enhance the dramatic possibilities that sound has given to the motion picture.

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[2] LEVINSON, N.: "A New Method of Increasing the Volume Range of Talking Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XXVI** (Feb., 1936), p. 111.

DISCUSSION

MR. ALBERSCHEIM: Have other studios, using other recording methods, had the same experiences with the audience, and is the wearing of film, as well as the masking of the audience noise, selective to the recording methods used?

MR. MUELLER:* We experienced this difficulty only when we began using a recording system having available a wide volume range. We were impressed with the dramatic results of these wide-range recordings and began releasing pictures in the theaters with the results outlined in my paper.

In order to determine why this effect had not shown up in our previous recordings with the variable-density system, we measured the volume range of a number of our pictures previously released and found that they were compressed into a narrow volume range much more restricted than I recommend in my paper. This was found to be true also of the recordings of all producers using variable-density sound and can be very easily verified by anyone with a true instantaneous peak-reading volume indicator such as the neon volume indicator which we use.

Going still further, we determined that the cause of the compression in our own variable-density recordings was (*1*) compression due to the photographic characteristic, and (*2*) volume limiter action due to overloading by as much as 8 or 10 db. At that time (1936) we reduced the percentage modulation in our variable-density recordings, as read by a neon volume indicator, so that no overloading took place, and we found that much of the compression disappeared, but that due to the 8-db drop in recording level, the reproduced noise was too high to be satisfactory.

As previously pointed out,[2] a variable-density recording with the same percentage modulation should be about 8 db lower in level than a variable-area recording. The variable-density recordings being released in Hollywood at present run on the same fader settings as our variable-area recordings, indicating that the limiter type compression mentioned above is still present, and peak-reading volume indicator measurements also show that the variable-density pictures still have the greatly restricted volume range. Consequently, producers using variable-density records have not had this difficulty because their recordings are compressed more than the ranges recommended in my paper, with the consequent penalty of serious overloading not present in properly produced variable-area recordings.

MR. KELLOGG: I gather that there is not much that can be done toward reducing audience noise. Presumably that is true from the standpoint from which the paper is written, namely, what can the producers do about it? However, there is no question that greater sound absorption in the theaters would very materially reduce audience noise. The audience is competing with itself to be heard. People talk to each other, and the louder the noises from other sources, the louder they talk. There is further quieting of the audience due to the psychological effect of removing sources of noise such as ventilation systems, and of reducing noise by means of absorption. I should think that the possibility of increasing the volume range by means of sound absorption and making it up by more output in the sound system certainly looks hopeful.

* Communicated,

DR. GAGE: In the reviewing rooms would it be desirable to have a sound-source equivalent to an audience, so that the reviewers might judge whether the dialog in the films was of correct volume to be intelligible in spite of this interference?

MR. RYDER: It is very difficult to judge playing levels in a review room where one is deprived of audience reaction. I have been following previews ever since the advent of sound, and even now I find that I miss in level settings prior to the first preview. I still depend upon hearing the picture with an audience for the establishment of the proper playing level.

MR. MUELLER:* The measurements were averages of tests made in a number of theaters with different types of audiences and different types of pictures. Audience noise varies with the type of audience, the type of picture, and the scenes in the picture, and as stated in the paper, noise levels were found as low as +32 db and as high as +48 db. We can not make our pictures to suit the best or the worst noise conditions prevailing in the theaters, and we selected an average noise level as being the most logical compromise.

I do not agree with a suggestion that has been made that the signal level be dropped 12 or 15 db below the audience noise. An audience may quiet down 5 or 6 db for a dramatic, low-spoken scene if the scene is not too long. However, as soon as the scene is over, the noise level will rise above normal as the people readjust themselves in their seats and make themselves comfortable again.

Any producer who released pictures based on the premise that the audience must be very quiet to enjoy them would be facing disaster. It has been our experience that the product must be fitted to the requirements of the average theater and theatergoer rather than that the audience must be conditioned or educated to suit the picture. We know of no formula to make an audience behave in a manner to suit the ideas of a producer of pictures.

MR. ALBERSCHEIM: The wear of a film depends upon the type of track and other factors. Also, as has been pointed out, audience noise is selective to the dramatic content of the story, and perhaps in some theaters, if the story is a good one, the audience noise may be found at a level of only 32 db. Have other studios had the same experience with regard to volume range, or have you been able to put more volume range on your film without difficulty?

MR. RYDER: Actually we have experienced a slight decline in volume range or in volume output from film, but not as a result of wear. The decline is the result of oil stains, and stains resulting from cleaning. Many of the cleaning processes are merely smearing processes.

I hesitate to express a definite opinion regarding the desirable volume range of the future. The desirable volume range will depend upon the theater's carrying capacity. Mr. Mueller pointed out that Warners are at the moment limiting their volume range to meet the conditions in the field. Our activity at Paramount has been one of pushing the theaters a little, with the hope of bringing more theaters into line so that they can reproduce sound to better advantage and put on a better show.

MR. FRIEDL: It seems significant that the average dialog level was tabulated at +65, which is the reference reading on the noise-meter or the measuring instrument, as acoustic energy in the auditorium. I believe the author also said they could not raise the average level of dialog. Let us assume that modern

theater equipment provides adequate capacity and power for that average dialog range. We are still limited in the volume range of dialog by the noise coming up to meet it. The increase in power will, perhaps, lend more dramatic effect to the music. But what about the dialog? We can not have average dialog at a shouting level; it has to be convincing.

MR. RYDER: In the *Spawn of the North* we had important dialog occurring during the crashing of icebergs and other loud-effects parts of the picture. In certain theaters one would hardly know there was any dialog because the effects so overloaded the equipment. In other theaters the dialog was distinctly heard and understood by the audience, carrying real meaning and adding dramatic value to the story. There is reason for having power beyond what is required for normal dialog reproduction. In general, I agree that dialog should not be pushed to levels where it is no longer real or convincing to the audience, although at times we have probably offended, along with others, in that regard.

MR. OFFENHAUSER: Where do you place a measuring microphone in a case like this; and what sort of microphone do you use?

MR. MUELLER:* The microphone was placed in the center right and left sections of the seats in the main floor of the theater or in the balcony. A series of measurements was taken with the microphone one-fourth of the way back from the front seats and also at a position three-fourths of the way back. The measurements given are averages of six positions in the case of a stadium type theater or twelve positions if the theater had a balcony. A crystal microphone is used.

MR. FRIEDL: In the data presented the dialog and music, as measured in the same units, were run at about the same level, that is, in both the theater and review room. I think I recall seeing +74 as the level. Can you operate at as high an output level in the small room as in the theater?

MR. RYDER: The output level from the horn—no; the actual level to the listener—yes; even higher in small review rooms, before it becomes objectionable.

MR. FRIEDL: You are not overriding audience noise there, because the noise of the room is less. There were no measurements of an audience in the small review room. There *must* be an audience, of course, but it is negligible in terms of numbers, for noise.

Mr. Mueller points out that in trying to take advantage of all the new fine-grained emulsions, and the low noise of the amplifier systems, as these factors contribute to extending the volume range, we find that the limiting factor seems to be the audience noise; we have to do something to quiet the audience—perhaps by putting carpet underneath the seats, or something like that. Evidently merely increasing the power output will not accomplish the desired result.

MR. RYDER: We have encountered still a different factor in suppressing noise by acoustic treatment. The Arlington Theater in Santa Barbara was recently treated, at a cost of about $16,000, and has since not been desirable for previews. The deadening of the house has created an unfavorable situation. Although it is not completely dead, it is so dead that the audience does not react normally. People begin to laugh and are stifled; they do not get the reinforcement of the complete audience. As a result, the audience does not laugh as much as they normally would, and they lose part of the enjoyment of the show. It is our feel-

ing that group laughter contributes to the pleasure and enjoyment of motion picture entertainment.

MR. FRIEDL: In other words, it is not how much one personally enjoys it, but how much the other fellow is enjoying it, which also stimulates one to enjoy it more. As Mr. Kellogg stated, we may require optimum reverberation limits to reduce the noise and increase the volume range; and not get so much out of the laughs but rather more enjoyment and relaxation.

What we are trying to deliver to the audience is a complex thing—enjoying dialog and a good volume range and a good play, and not just the laughter or noise of the theater.

MR. RYDER: The pleasure of the audience is what we are after, and while my reaction follows the reaction of our production group, we may all be in error. They have a very definite reaction against any house in which the audience does not feel free to laugh. It is surprising how a dead room tends to prevent laughter. Our thought in this regard has been substantiated by the preview cards which we receive from the various theaters.

In the case of the Santa Barbara theater, we were able to obtain a normal audience reaction prior to the acoustic treatment even though the house had a bad echo. Subsequently to the deadening we took pictures to the house and obtained a lifeless reaction from the audience, after which the same pictures were taken to other theaters where we obtained a normal reaction.

MR. KELLOGG: Mr. Ryder has brought out a very interesting point about the stifling effect of too much sound absorption on audience reaction. It seems clear to me, now that he has mentioned it, that the expedient I proposed for reducing audience noise could do much more harm than good.

MR. ROBERTS: I do not believe a low degree of audience noise is objectionable, because we become accustomed to it. It is annoying for me to go into a theater where there is a high degree of noise, after being accustomed to the silence of review rooms. Perhaps, everyone could be conditioned to a low noise level in the theater.

MR. MCNABB: There is a great difference among people with regard to the level at which they like to listen to music or dialog. For instance, a man who works in a noisy factory will, when he returns home at night, adjust his radio to a level much higher than his wife would like to listen to, because she is used to the quietness of the home. If the majority of theatergoers live in noisy cities, we must adjust to a higher level to satisfy them. If the majority of listeners are people who live in quiet surroundings, it means that we should have a lower level.

MR. RYDER: There is a difference between audiences in that regard. A tired audience such as is encountered in an industrial section such as Whittier or southeast Los Angeles will react differently than a Beverly Hills, Westwood, or Pasadena audience. Apparently it takes more volume for a tired audience.

Nerve strain is another thing that affects hearing, a fact that has been recognized for some time. A director or producer going to a preview is always under a strain, which frequently affects his hearing.

MR. SEELEY: There is also a big difference in auditoriums. The absorption is no doubt an important factor, and I rather imagine that the shaping factors are very important. That would seem to indicate that the ideal type of volume

expansion would, if such a thing were possible, be adjustable to the individual house, and perhaps to the individual audience. For example, on Saturday afternoon, when the children are in the theater, it would be different from what would be required at other times.

MR. HOVER: Those who work with audiences of 6000 to 10,000 persons often are unable to drop the noise level of the audience sufficiently so that their equipment will work well. The usual system is to drop the gain gradually to the point where the audience will have to be quiet to hear the speaker. That works only so far, however, because as soon as the audience misses one or two words, immediately the noise level goes up. The psychological hold on the audience has been lost.

MR. MCNABB: Loud entrance music automatically raises the level to which people want to listen, and is usually too loud. If the entrance music level were kept low, it would tend to keep the audience quieter.

MR. RYDER: There is a great deal of controversy in Hollywood as to the proper volume for main and end titles. It is somewhat like the newsreel problem, where each is trying to outdo the other, with no thought of getting into direct competition.

MR. BATSEL: Mr. Mueller's point, I believe, was that compression aids intelligibility in the presence of noise. That has been confirmed by experience in the use of announcing systems in industrial establishments and other places where there is noise to contend with.

MR. SEELEY: A person seems to be more annoyed by a noise that he does not quite know, or the presence of which he is not sure, as well as the fact that the noise may not be justified. For instance, a person walking down the aisle is not quite so annoying as one who is opening a box of candy in the next seat. Those factors I think should be considered.

MR. RYDER: That ties in with the thought that the tests made here were monaural as compared with binoral listening. All our sound, including disturbing noises, comes from the screen, a point-source. If the audience is listening to sound from that source (the screen) and disturbing sounds also come from there, the disturbing sounds are much more objectionable than if they are introduced off to the side, where the audience can discriminate against them.

PARTIAL DEAFNESS AND HEARING-AID DESIGN*

I. CHARACTERISTICS OF HEARING LOSS IN VARIOUS TYPES OF DEAFNESS

WILLIS C. BEASLEY**

***Summary.**—This paper deals with certain aspects of the intricate relationship between the nature of hearing loss associated with various stages of impairment for hearing speech in everyday situations and the possibilities of improving physical therapy for the deafened through improvements in the design of hearing aids.*

The data, upon which the study is based, were obtained during a clinical study of deafness and aural disease conducted by the United States Public Health Service during the spring and summer of 1936.

Variations in the nature of hearing loss are shown for persons having the following stages of practical handicaps for hearing speech in everyday situations: (a) impairment for hearing at church, in the theater, and in group conversation; (b) impairment for hearing conversation at close range; (c) impairment for hearing over the telephone; and (d) inability to hear speech under any circumstances.

Students of physical therapy† for the deafened have observed for many years that only a small percentage of hard-of-hearing persons who actually try out portable electrical hearing aids regard them as being sufficiently helpful to justify the expense and annoyance involved in using them. Moreover, it has been estimated from a recent survey of deafness in the general population that hearing aids

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.

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† Therapeutics, in the general sense, is the practical branch of medicine dealing with the curative treatment of disease. Physical therapy, which is only one small phase of the broad field of medical therapy, deals with the prescription of artificial devices for curative or rectifying treatment of disease or physical impairments. Physical therapy for the deafened is limited almost entirely to the measurement of auditory acuity (by audiometers or other means) and the prescription of rectifying hearing aids. This field of physical therapy is in its infancy, and is in urgent need of systematic information. It is one purpose of this discussion to point out some of the unexplored areas where knowledge that is indispensable to progress is lacking.

of any type are being used by only 5 per cent of the persons who are sufficiently hard of hearing to derive benefit from them.* This proportion is significantly lower than that which exists for the use of physical therapeutic devices in relation to other handicaps, for example, crippled limbs or defective vision. It is clear, therefore, that a real problem, which has not been solved, exists in connection with the prescription, design, manufacture, and distribution of auricles.**

Even in the recent past, the view has been expressed widely that this limited use of auricles is due largely to mental factors peculiar to persons who are hard of hearing, especially their unwillingness to accept this type of therapy and their impatience in learning how to utilize the artificial aid to best advantage. It is said also that deafened persons expect more from auricles than the best engineering practice can possibly supply in light, portable (wearable) equipment at any price. On the other hand, many physicians and acoustical engineers alike are convinced that the appalling failure of this therapeutic service may be ascribed most properly to the fact that auricles, either of the vacuum-tube or carbon type, provide grossly inadequate corrections of auditory defects as they occur among most patients who seek amelioration of this handicap. And, finally, despite the gradual but continuous improvement in the performance characteristics of auricles during the past fifteen years, the available products are far short of what may be viewed as most desirable.

The testimony of hard-of-hearing patients should not be ignored in this prospectus. The writer has interviewed well over a thousand clinical patients in connection with the problem of auricles. While they present by no means a uniform front in regard to attitudes about

* This estimate is based on data obtained from the National Health Survey, which was conducted in 84 urban areas of the United States during the fall of 1935 and the winter and spring of 1936.

** The term "auricle" will be used in this study in the broad sense of any type of electrical hearing aid which is sufficiently light to be worn on the person without accessory equipment being required. The device is composed typically of the following units: microphone; amplifier unit, with volume control; either an air- or bone-conduction receiver; and power supply (usually dry-cell batteries). In addition to auricles, semi-portable hearing aids, which are larger and require separate carrying cases, and group hearing aids, which are used in churches, schools, and theaters, are now in use and are available commercially. An auricle may be considered as a device that is intended to correct defective hearing somewhat in the manner that spectacles are employed to compensate for defective vision. The therapeutic problems, however, as will be pointed out later in this discussion, are entirely different in regard to auricles and spectacles.

hearing aids, some views occur much more often than others. The numerous reasons, which are usually given in the clinical history, as to why individuals reject or even refuse to try out hearing aids may be classified suitably under three headings: personal pride, prohibitive cost, and poor performance. It is true that some people do not wear hearing aids for the sake of personal pride. There is serious objection to advertising one's defect by wearing "the crutch" in plain sight. Such attitudes are infrequent and are rapidly becoming more so. This is easily understood. Persons with any type of handicap soon are forced to accept the fact of its existence, and are not only willing but anxious to secure remedial treatment, even when the latter requires wearing a device of one sort or another.

Prohibitive cost and poor performance are given about equally often as reasons for rejecting hearing aids. And these two reasons, separately or combined, express the attitude of more than 90 per cent of hard-of-hearing persons who have not bought hearing aids for themselves. There is a measure of interdependence, however, between these reasons. Hearing aids are in disrepute among hard-of-hearing persons. So many people have found them unsatisfactory that others who are contemplating trying them out are discouraged by either first-hand or second-hand reports. The best salesman is a product that perpetually reaches satisfied consumers.

In this connection, attention is invited to the fact that deafness courts both economic and social hazards. Deafness increases unemployment risk.* Deafness discourages free and spontaneous social communication. Hard-of-hearing persons soon learn the force of these two facts. They seek to remove both handicaps by every available means. Satisfactory performance of auricles is bound, therefore, to outweigh purchase price in the final analysis. Persons who are handicapped by impaired hearing want, and one may add, desperately, an auricle which will assist them materially in their jobs and in their daily living. Driven by almost reckless desire for alleviation, they often accept less than worthless devices which soon are

* During the depression and the immediate sequel thereto, hard-of-hearing persons lost their jobs from two to three times more often than persons with normal hearing in the same occupational groups. Partial deafness proved to be a greater employment liability for professional and business persons than for unskilled workers. These facts were disclosed by as yet unpublished results from the National Health Survey.

discarded. When better auricles are available, undoubtedly there will be fewer complaints about purchase price and appearance.

To some extent, at least, it is expected that performance characteristics of auricles and their retail price should be directly related. However, at present there are only a few manufacturing concerns with sufficient volume of business to put auricles of high-quality construction (according to present standards) on the market at a reasonable price. On the other hand, there is a large number of small-scale manufacturers who distribute auricles of definitely inferior grade at a price which competes with the better products. The operations of these smaller firms constitute a definite hindrance to systematic progress, inasmuch as they contribute mainly to enlarging the field of dissatisfied customers. But even the most expensive and best constructed auricles from the standpoint of mechanical ruggedness and high-quality materials do not solve in even an approximately satisfactory manner the problem of aural rectification. This is borne out by the large proportion of deafened persons who give them fair trial but find them to be of little benefit.

The major obstacles to providing immediately better service in the field of physical therapy for the deafened than that which is now available apparently overlap into several fields of science and practical effort. The first steps in removing these barriers consist in carrying out a coördinated research program that will provide the following:

(*1*) Extensive information on the fundamental psychophysical properties of deafened ears, especially in regard to the perception of tones and speech sounds at optimal levels above threshold intensities.

(*2*) Development of reliable statistics on the prevalence and distribution of various types and stages of deafness in the general population.

(*3*) Specifications for the response-frequency and other functional characteristics of sound amplifiers that will compensate most adequately for different patterns and degrees of hearing loss.

(*4*) New circuit designs and new functional parts that will enable engineers to provide the desired optimal and selective amplification in the form of wearable and relatively inexpensive auricles.

(*5*) Simplified, standardized, and reliable diagnostic and aural testing procedures that will enable the physician, or his technical assistant, to derive from the results of an examination a prescription for the most beneficial type of auricle for an individual patient.

(*6*) Means by which the patient can obtain a reliable fitting in accordance with standardized practice once the proper prescription has been provided.

(*7*) Means by which the patient can be taught properly how to use the auricle to best advantage and obtain periodic recheck examinations.

(*8*) Means for controlling the manufacture of auricles, so that they must be certified as being in accordance with adopted standards. The basis for standardization can be accomplished through the information described under items *1*, *2*, *3*, and *4* above.

Not until adequate knowledge of this type becomes available can any certain steps be taken in the direction of standardizing auricles or improving the service to patients. It is possible, of course, even when the requisite information is available for writing optimal prescriptions for auricles that the specifications can not be incorporated into the desired wearable auricle by any known engineering technics and products. Nevertheless, knowledge on the nature of deafness itself is the basis for defining just what the engineer's problem consists in.

The present series of papers is intended to provide a contribution to one small, but fundamental, phase of this rather involved problem: namely, data which show the nature of hearing losses associated with several degrees of practical handicaps in hearing speech under everyday situations, and the relative frequency of occurrence of various patterns of hearing loss. The discussion in the first paper is confined largely to a description of the patterns of hearing loss in relation to degree of handicap for hearing speech. The second paper in this series will deal with statistical estimates on the prevalence of the various types of hearing loss in the general population in urban areas of the United States. It is thought that data of this type should provide a basis for determining characteristics for hearing aids that are needed most often.

THE MEASUREMENT OF AUDITORY ACUITY

There are many ways of describing, classifying, diagnosing, and measuring deafness or loss of normal hearing. During the latter half of the nineteenth century, deafness was measured mainly by the following methods: (*a*) the maximum distance at which spoken or whispered words could be understood, (*b*) the highest pitch of a tuning fork that could be heard at all, and (*c*) the maximum time a

vibrating tuning fork could be heard when held about half an inch from the opening of the ear canal (air conduction) or when the stem was pressed against a mastoid process (bone conduction). With the advent of various methods for generating alternating current, the technic known now as "audiometry" was introduced for the purpose of measuring in physical units the acuity of hearing for pure tones.

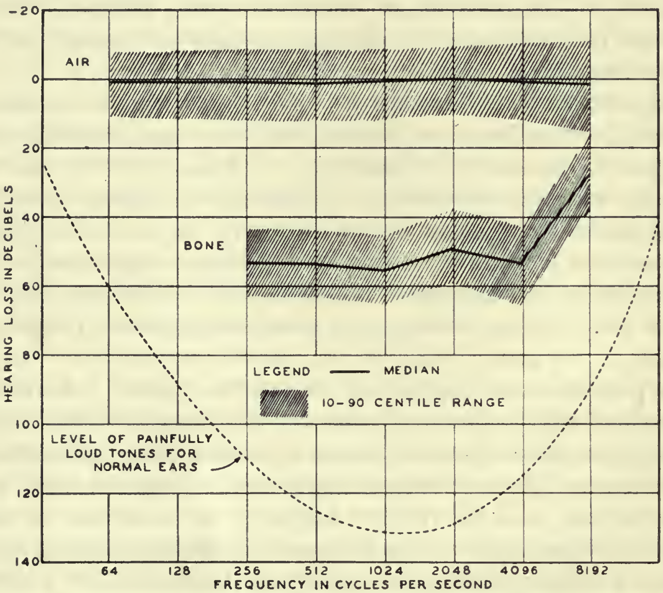

FIG. 1. Audiogram chart showing characteristic ranges of auditory acuity by air and bone conduction for 1663 persons whose hearing is normal in all respects.

There are several types of audiometers available commercially, but most of them given reasonably comparable results when proper attention has been given to the zero calibration of the instruments and to the characteristics of the receivers. The data upon which the present study is based were obtained with the Western Electric *2A* audiometer. This instrument provides an output of eight pure tones spaced at octave intervals from 64 to 8192 cycles per second, over the intensity ranges indicated in Fig. 1. The vertical ordinates on this chart indicate the frequency level of sound, and the horizontal ordinates mark off levels of sound intensity relative to a normal average

zero reference. Negative values on this scale indicate better than average normal acuity, and positive values indicate loss of acuity.

Two types of receivers were used with this audiometer: (*a*) for air conduction the Western Electric Type *552W* receiver, and (*b*) for bone conduction the Type *700B* receiver. The ranges of hearing loss for both air- and bone-conduction measurements obtained for 1663 persons having normal auditory acuity are shown by the shaded areas (Fig. 1).* The median hearing loss for this group is indicated by the heavy line near the middle of the shaded areas. Hearing losses in Figs. 2 to 10, inclusive, are given as deviations in decibel units from the median values for this normal group.

The *700B* bone-conduction receivers were placed against the mastoid process (bony lump behind the external ear), where they were held in place by means of steel spring headbands. These receivers are driven by alternating current from the audiometer. Since more energy is required to drive the bone-conduction receivers than that required for the air-conduction receivers, sufficiently to elicit a just-perceptible tone, the normal value for bone-conduction thresholds (Fig. 1) is at a greater level of "hearing loss" than that for the normal air-conduction thresholds.

The double bars on the chart indicate the maximum hearing loss levels which can be measured by means of the Western Electric *2A* audiometer. The dashed line on the lower portion of the chart, labelled "total loss of serviceable hearing," indicates the intensity levels which produce sounds that are painfully loud to persons with normal hearing. This region also indicates approximately the minimum hearing loss for "absolute" deafness.

In the testing procedure followed during this study, the operator of the instrument presented the patient with a tone that was above threshold (except cases whose loss was near to or greater than the maximum output of the audiometer). The operator ascertained the minimum intensity level at which the patient consistently indicated that he heard the test tone. The average value for several readings obtained in this manner was used as the final measure of acuity. A line connecting the average threshold points (illustrated in Figs. 3, 5, 7, 9, and 11) gives a profile graph or audiogram of the person's acuity. An audiogram shows the extent of deviation of an individual's

* These measurements were made during a clinical study of hearing, which was operated under the direction of the writer in twelve cities during the spring and summer of 1936.

hearing for the various pure tones relative to the normal standard of reference.

Ordinarily, it is considered that values within ± 10 db of the average or median normal are simply chance variations of measurement and may be regarded as normal in all respects. Loss of acuity to the extent of 20 db or more indicates defective hearing. The greater the amount of hearing loss, of course, the more serious the defect.

DIAGNOSIS OF LESIONS BY AUDIOMETRIC TECHNIC

The purpose in using both air- and bone-conduction receivers in measuring auditory acuity is to aid the physician in determining whether hearing loss by air conduction is accompanied by equivalent loss by bone conduction, and to provide clues for the diagnosis of nerve deafness. When hearing losses by both methods of measurement are equivalent to each other, the deafness is called perceptive or "nerve deafness" and indicates usually that the defective hearing may be attributed to one or more of the following conditions: (*a*) primary degeneration of sensory nerve-endings in the inner ear (cochlea), (*b*) degeneration of acoustic ganglion cells, (*c*) degeneration of afferent nerve fibers in the acoustic nerve, or (*d*) lesions in the central pathways of the brain (temporal lobe, or other loci). In rare cases, this type of result may be observed when there are no nerve lesions at all, but there is some type of bone-conduction impedance in excess of the normal condition. Diagnosis of nerve lesions by this method alone is not absolutely final.

When there is considerable hearing loss by air conduction, but the bone-conduction response is normal, the defect of hearing is attributed usually to conductive lesions in the middle ear. Some examples of conductive lesions are the following: (*a*) perforated eardrum; (*b*) retracted malleus and concave drum membrane; (*c*) absence of drum membrane, malleus and incus; (*d*) adhesions of injured tissues in the middle ear, which reduce mobility of eardrum and ossicles; (*e*) sclerosis of tissues in the labyrinth and middle ear; (*f*) suppurative discharges at various loci of the middle and inner ear.

Sometimes a distinction is made between *obstructive* and *conductive* lesions. For instance, a suppurative occlusion of the middle ear or ankylosis of the stapes interferes (obstructs) mechanical transmission of air-conducted sounds, whereas under these circumstances bone-conduction acuity is better than normal due to a compression action within the cochlea.

Conductive lesions influence the hearing in several ways: (*a*) acuity by air conduction may be reduced on all tones by approximately equal amounts, while acuity by bone conduction remains normal on all tones, (*b*) acuity by air conduction may be reduced on all tones, but relatively more for tones lower in frequency than 500 cycles, while the acuity by bone conduction remains normal for tones higher in frequency than 500 cycles but is better than normal for lower tones, (*c*) acuity by both air and bone conduction is reduced on all tones, but proportionately more by air conduction on some middle and low tones (64 to 512 cycles) and about equally on high tones (4096 and 8192 cycles). Such diagnoses can not be accomplished with certainty by audiometric technic alone.

Nerve deafness may influence the hearing for some or all tones, conductive lesions may reduce acuity for some tones and not for others. In the same ear, moreover, loss of acuity on some tones may be due to conductive lesions, and on other tones the loss may be due to nerve lesions. In the latter case the deafness is regarded as being of a "mixed type." Combined conditions of obstructive, conductive, and nerve lesions may exist in the same ear. There are two major reasons why it is important to determine the extent to which cases of deafness are of the pure nerve type, the pure conductive type, the pure obstructive type, or of the mixed type: (*a*) the prognosis for treatment differs for various kinds of lesions, and (*b*) the hearing for sounds well above one's own threshold value varies with the type of lesion. Because important pathology may be present in such degree as to render inadvisable the use of a hearing aid, persons contemplating trial of this device should consult a medical specialist before deciding. Moreover, measurements by the threshold acuity technic alone do not provide accurate predictions for the ability to hear sounds well above threshold. The amount and kind of error involved in making these predictions differ notably for the various types of deafness, depending on the nature and extent of conductive, obstructive, and nerve lesions involved. The magnitude of sound intensities which the diseased ear can tolerate without pain or serious discomfort also varies with the type of deafness and organic condition of the ear.

DEFINITIONS FOR CLINICAL HISTORY OF IMPAIRED HEARING

Partial deafness may be measured in terms of (*a*) audiograms showing loss of acuity by air and bone conduction, (*b*) loudness contours

indicating response to sounds which are well above threshold intensities, (*c*) speech articulation tests, and (*d*) language intelligibility tests. A fifth equally important method for classifying aural handicaps is the clinical history, which utilizes certain explicit definitions of auditory experience. The patient's testimony is classified in accordance with definitions, which specify gradations in severity of deafness in relation to practical situations. Regardless of refinements incorporated in instrumental technics, it is ultimately of practical importance to know what correlation exists between the results of objective tests and the usual experience of the individual in communicating with others by vocal-aural transmission. The clinical history technic requires, of course, careful attention to the manner of conducting an interview with the patient, quite as much as audiometric technic requires uniform and standardized procedures in conducting objective tests of hearing. And the results from both methods are equally useful when appropriate limitations are imposed on interpretation of results obtained by either technic.

In the spring and summer of 1936, the United States Public Health Service conducted a clinical investigation of hearing at 17 temporary otological clinics which were operated under the direction of the writer. These clinics were located in 12 cities in the eastern half of the United States. Audiometric tests and otological examinations were given to some 9000 males and females ranging in age from 8 to 90 years.

Each clinical patient was interviewed by a physician. A standard series of questions was employed during this interview, and each patient's experience in regard to his hearing ability was classified according to one of the following categories, depending upon which definition applied most directly to his case:

(*1*) *Normal Hearing for Speech.*—The person had never experienced difficulty at any time with his hearing.

(*2*) *Partial Deafness, Stage 1.*—The person experienced difficulty in hearing speech at the theater, in church, or at a conference of five or six persons, but could understand direct conversation satisfactorily.

(*3*) *Partial Deafness, Stage 2.*—The person experienced difficulty in hearing ordinary direct conversation, but could hear loud speech, telephonic conversation, or speech amplified by other means.

(*4*) *Partial Deafness, Stage 3.*—The person experienced difficulty in hearing ordinary telephonic conversation, but could hear speech by

means of amplifiers such as telephone amplifiers, electrical hearing aids, *etc.*

(5) *Total Deafness for Speech.*—The person could not understand speech under any circumstances, even by means of amplifiers, but the impairment was acquired after the person had learned to speak language by ordinary methods of training.

(6) *Deaf-Mute.*—The person was born deaf or acquired severe deafness at such an early age that he did not learn to speak language by ordinary means.

During this clinical investigation, measurements of auditory acuity were taken on eight tones by air conduction and six tones by bone conduction with Western Electric *2A* audiometers and their associated receivers. All instruments and receivers were calibrated prior to, during, and after the survey by expert technicians of the Bell Telephone Laboratories. Measurements were taken in specially constructed sound-insulated booths. Thorough oto-rhino-laryngological examinations were made on each subject and extensive medical histories and personal data were obtained in addition to the clinical history of auditory experience.

CHARACTERISTIC TRENDS IN ACUITY

For the purposes of this study, the measurements of auditory acuity were classified in groups according to the clinical history of hearing ability separately for all females under 25 years of age, and for all males 45 years of age and over. All the measurements on each test tone, for example, were classified in tabular form showing the number of measurements at each setting of the audiometer intensity control. Such an array of data is referred to as a frequency distribution. The hearing loss level was computed, in accordance with standard statistical procedure, for each of the following percentages of the total number of measurements in a given frequency distribution: 10, 25, 50, 75, and 90 per cent. The computed hearing loss values at each of these percentage levels were employed in plotting the graphs shown in Figs. 2, 4, 6, 8, and 10.

The graphic contours, which result from connecting the points for a given percentage value, will be referred to conveniently as "percentage audiograms." Thus, the family of percentage audiograms for all females under 25 years of age having a clinical history of normal hearing is illustrated in Fig. 2*A*. The contour labelled "10 per cent" at the right indicates the hearing loss level on the seven test tones at

which, cumulatively from the lowest values (least hearing loss) in the frequency distribution, 10 per cent of the measurements occur. In a similar way, the other percentage audiograms indicate in graphic form the hearing loss levels at which specified percentages of measurements, relative to the most sensitive ear, occur for each group of subjects.

These contours may be regarded as depicting statistical trends for a group, not as representing a hypothetical average person. In general, the scalar distances between the percentage points on each ordinate give an estimate of the dispersion of measurements in relation to the central tendency, which is indicated by the median value (50 per cent contour). Instances in which the distances between these percentage points are relatively longer indicate greater variability in the relationship between hearing loss, or measurement of acuity, and the testimony of the patient in regard to his auditory experience, when the latter is classified according to the clinical history definitions given above. By comparing these distances between the points for individual tones in a family of contours for a given clinical history, one may draw conclusions regarding the extent to which indicated ranges of hearing loss are more critically related to some tones than to others for that type of auditory experience. Comparisons of this type are made below in relation to each group.

In cases where the distances between these percentage points are approximately equal for a given frequency distribution, the measurements tend to be symmetrically distributed about the median value. Two other features of the frequency distributions enter into the discussion: positive and negative skewness. When the distances of the 75 and 90 per cent points from the median (50 per cent point) are greater than the distances of the 25 and 10 per cent points from the median, the distribution of measurements is skewed positively. In such cases there is a definite trend for deviations from the median in one direction (greater hearing loss) to be larger in value than those in the opposite direction. When skewness is the reverse of this type, the distribution of measurements is said to be negatively skewed. Interpretation of statistical trends shown by the various families of percentage audiograms should take into account the degrees of dispersion, as well as the sign and magnitude of skewness, for distributions of measurements on the various tones.

The central 50 per cent of the measurements for each family of percentage audiograms is indicated by the distance between the 25

and 75 per cent audiograms. It is believed that this area may be regarded as the most characteristic range of hearing loss that is associated with a given type of clinical history.

NORMAL HEARING FOR SPEECH

Characteristic ranges of hearing loss found among persons having a clinical history of normal hearing for speech are shown by the percentage audiograms in Fig. 2. The most frequent types of individual cases usually encountered among males and females in three broad age groups (under 25 years, between 25 and 45 years, and 45 years of age and over) are illustrated by the audiograms in Fig. 3.

More than 90 per cent of the females under 25 years of age have normal audiograms for both air and bone conduction. Males 45 years of age and over have normal audiograms in less than 30 per cent of the cases. The type of defect which occurs most often among the older males, and to a lesser extent among older females, consists in nerve lesions involving loss of acuity for the two highest tones. This hearing loss is of such a character, however, that the persons have very little difficulty hearing tones or speech sounds that are 60 or more db above normal threshold intensity. Hence, they are unaware of the defect before it has been disclosed by audiometric technic.

STAGE 1 DEAFNESS

Cases of stage 1 deafness are of considerable importance, although there has been a tendency to disregard them, especially in relation to the problem of hearing aids. In accordance with the definition, stage 1 deafness includes impairment for distant speech, such as that encountered at the theater, in church, and in other public auditoriums as well as during group conferences. Although the handicap itself is somewhat manageable, the degrees of hearing loss associated with this stage of deafness are sufficient to warrant the use of properly designed hearing aids. From a technical standpoint, the types of hearing aid which would serve these patients well should be a fairly simple matter for the engineer. Hearing aids themselves are not sufficiently popular at the present time to attract the attention of persons having a degree of handicap indicated by stage 1 deafness. If the custom of using hearing aids were considerably more widespread than at present, there is little doubt that a large number of people in the stage 1 deaf-

ness group would be inclined to use a hearing aid for certain occasions in which they now experience their major difficulties.

Persons with this type of impairment would derive quite as much practical benefit through the use of suitably designed hearing aids as persons with minor degrees of astigmatism, hyperopia, or myopia derive from properly determined lens corrections. Just as persons

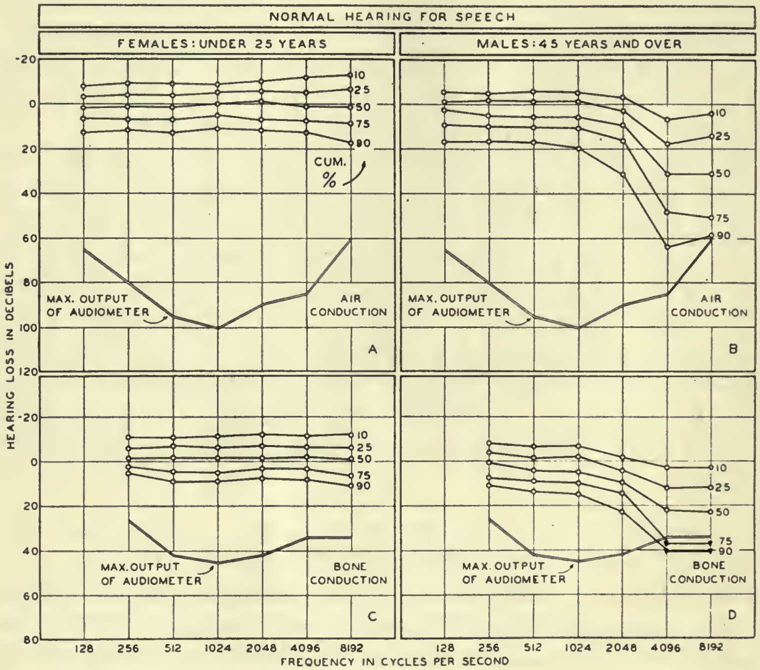

FIG. 2. Percentage audiograms showing characteristic ranges of hearing loss by air and bone conduction for females under 25 years of age, and males 45 years of age and over, having a clinical history of normal hearing for speech.

with minor visual defects manage to get along under most visual circumstances without spectacles, so persons with stage 1 deafness manage to get along without artificial hearing devices. However, there are numerous situations in which people with stage 1 deafness would benefit appreciably if they could produce at will a gain of some 20 or 30 decibels in the intensity level of received speech, or could amplify differentially the higher frequencies in the received speech without altering the middle and low frequencies.

The families of percentage audiograms illustrated in Fig. 4 show the ranges of hearing loss that characterize stage 1 deafness as it oc-

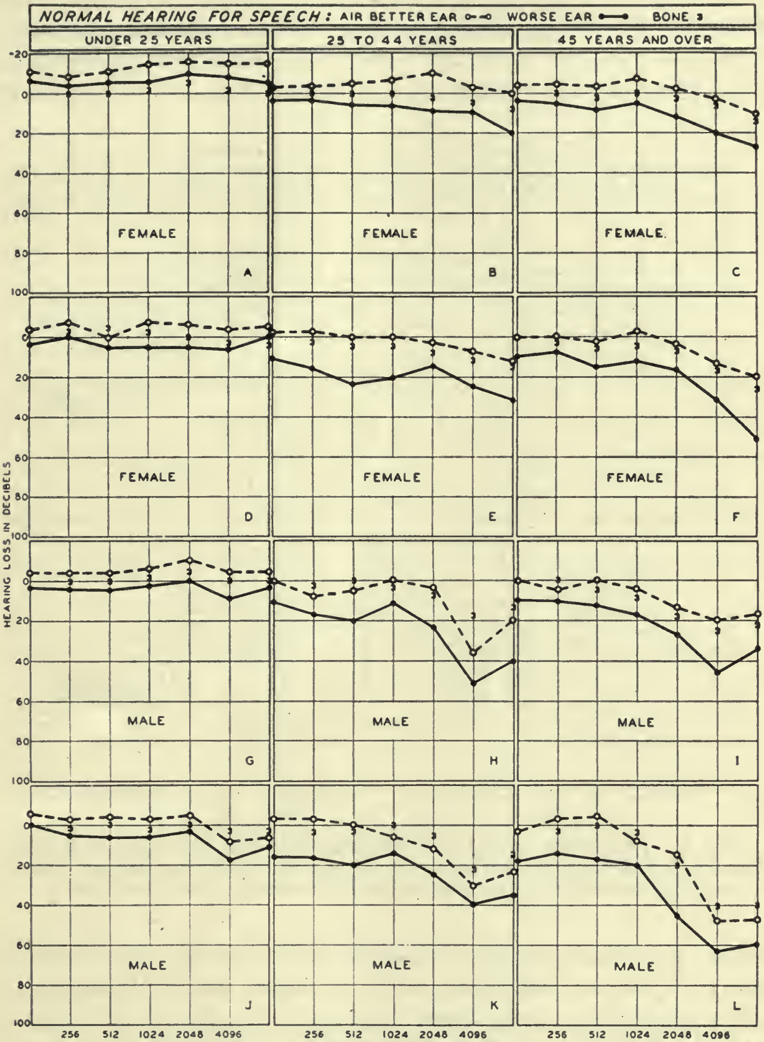

FIG. 3. Individual cases illustrating the various types of hearing losses which occur among persons having no noticeable difficulty with hearing.

curs among females under 25 years of age and males 45 years of age and over. Individual cases are illustrated in Fig. 5. The percentage

audiograms for females cover a rather wide range of hearing loss on each tone, but the fact that these percentage audiograms are approximately parallel is consistent with the fact that the individual audiograms of the persons included in this tabulation are most frequently horizontal. On the other hand, the audiograms for males (Fig. 4*B*) are parallel but each contour slopes gradually from left to right on the

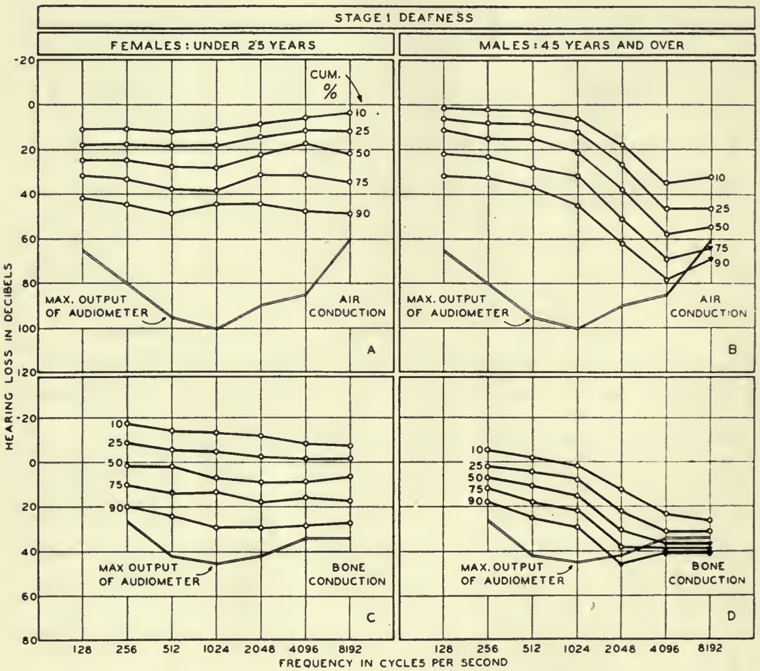

FIG. 4. Percentage audiograms showing characteristic ranges of hearing loss by air and bone conduction for females under 25 years of age, and males 45 years of age and over, having a clinical history of stage 1 deafness.

chart. The whole family of audiograms for males shows approximately 15 db less loss than that for females on tones below 1024 cycles, whereas for tones above 1024 cycles the family of curves for males shows uniformly a hearing loss 20 decibels greater than that for females. It will be noted that the measurements for females on the three highest tones show relatively greater loss for tones below 1024 cycles than for tones above this level in 50 per cent of the cases. About 35 per cent of the audiograms in this group show a slight but

gradually increasing loss from low to high tones. The former trend is typical for deafness cases in which the impairment is due almost

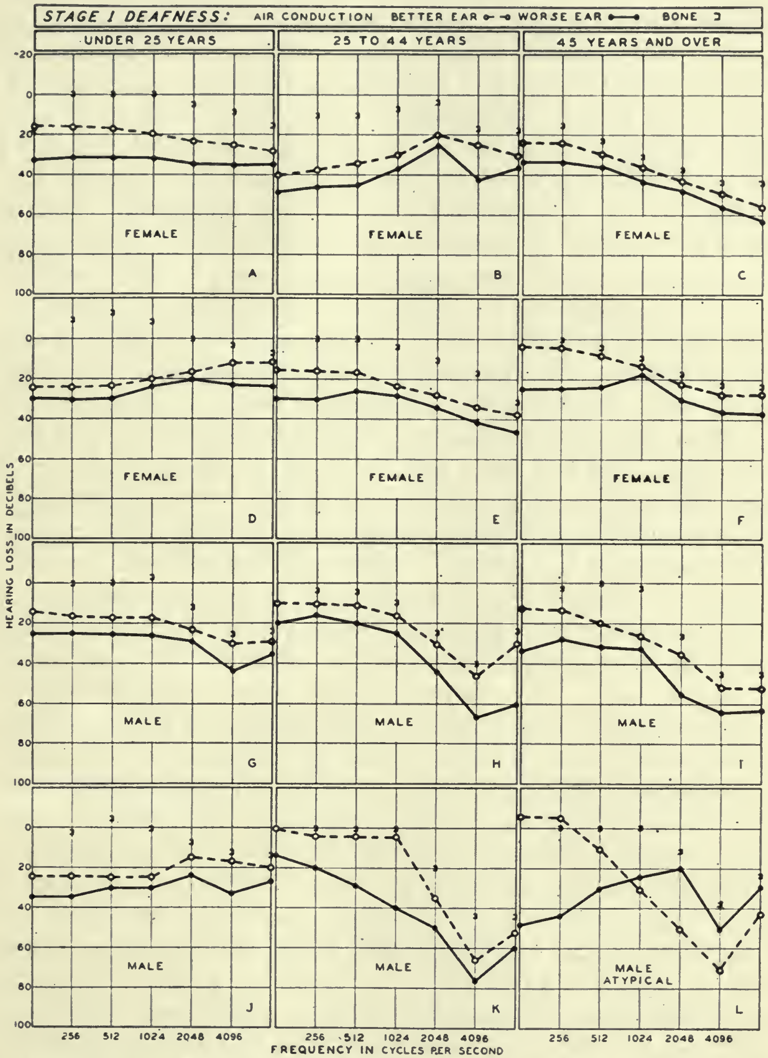

FIG. 5. Individual cases illustrating the various types of hearing losses which occur in stage 1 deafness.

entirely to conductive lesions in the middle ear. A further indication that these cases predominate among females under 25 years of age is

revealed by the nature of the percentage audiograms for bone conduction in Fig. 4*C*. There are relatively more cases of bone-conduction acuity at better than normal levels than are found among persons with normal hearing. On the other hand, the higher tones do not show a similar influence from conductive deafness. It appears that the vast majority of stage 1 deafness cases among females under 25 years of age may be considered as arising from conductive lesions, with relatively little nerve degeneration and involving typically a uniform hearing loss for all tones to the extent of 20 to 30 db by air conduction and no significant loss for bone conduction. Hearing aids which employ air-conduction receivers would be best suited to these persons, if they were capable of producing faithful amplification over the range 500 to 4000 cycles to the extent of about 25 db. Bone-conduction receivers which render speech intelligible to persons with normal hearing would also be suitable in the majority of cases. On the other hand, uniform amplification would probably not serve as well in improving the hearing of males 45 years of age and over. These cases typically show relatively greater loss for tones in the upper register for both air and bone conduction. This means that the impairment involved in stage 1 deafness among older males typically arises from nerve degeneration. Hearing loss of this type can not be rectified by means of artificial amplification in the same manner as impairments arising from conductive lesions. For the typical case in this group there is normal bone-conduction acuity for tones from 64 up to 512 cycles. For the higher tones, bone-conduction acuity is greatly reduced. A hearing aid which employs a bone-conduction receiver will rectify this type of auditory impairment satisfactorily if it supplies a differential gain in relation to frequency such that a person with this type of loss hears all tones with approximately normal loudness when the sounds external to the hearing-aid microphone are at intensities usually employed in speech. This type of hearing aid would have to produce zero gain for tones below 1000 cycles and about 35-db gain for tones above 3000 cycles, with proportionate gain between 1000 and 3000 cycles. On the other hand, a hearing aid which employs an air-conduction receiver would have to produce a gain of about 20 db for sounds below 1000 cycles and gradually increasing gain for sounds above 1000 cycles, reaching a maximum level of about 50-db gain at 4000 to 6000 cycles. These statements assume, of course, that the hearing aid is employed to remove the type of hearing difficulty reported upon by the patient. In cases of stage 1

deafness, this means difficulty in hearing speech in public auditoriums, in church, at the theater, and in group conferences. In such circumstances, sound intensities at the ear of the listener will vary greatly depending upon the speakers, the distance between the speaker and the listener, the amount of background noise, and the acoustical properties of the auditorium. It is probably safe to say that the average level above threshold for all these varying conditions at the ear of the listener will be about 40 to 50 decibels. Steinberg and Gardner's curves indicate that at this level, persons having a nerve deafness type of impairment recover only about 50 per cent of normal loudness.

STAGE 2 DEAFNESS

Cases classified under stage 2 deafness comprise those who experience difficulty understanding ordinary conversation at close range. For the most part, these persons can not hear at all in public auditoriums and similar situations in which the speech level at the ear of the listener is usually 50 decibels or less. Some of these cases can hear exceptionally well direct conversation uttered close to the ear, or can understand speech which has been amplified. Although there are quite a number of cases in this classification who would be expected to hear reasonably well over the telephone, there are many who could not do so without considerable amplification, such as that supplied at the present time by telephone companies for the private consumer's use.

By way of illustrating the amounts of hearing loss typically involved in stage 2 deafness among extremely different cases, percentage audiograms for females under 25 years of age and for males 45 years of age and over are depicted in Fig. 6. Typical cases for males and females of various ages having markedly different etiology are shown in Fig. 7. Among females under 25 years of age, more than 50 per cent of the hearing loss measurements for air conduction are distributed within the range 40 to 60 decibels. About 90 per cent of the measurements for tones above 500 cycles are distributed between 35 and 70 decibels. It is to be noted that measurements on 128 and 256 cycles cover a much wider range of hearing loss than those on the other tones. This means, of course, that the degree of hearing loss on these two tones does not influence ability to hear speech as much as the degree of hearing loss on higher tones. Secondly, that even at these marked levels of hearing loss there is a definite tendency for the amount of loss on the middle and high tones

to exceed that on the lower tones. This kind of trend predominates and characterizes the measurements among males 45 years of age and over who have stage 2 deafness. As shown in Fig. 6*B*, 50 per cent of the measurements on the males for 128 and 256 cycles are less than 30 decibels, whereas on 1024 and 2048 cycles more than 50 per cent of the measurements are in excess of 50 decibels.

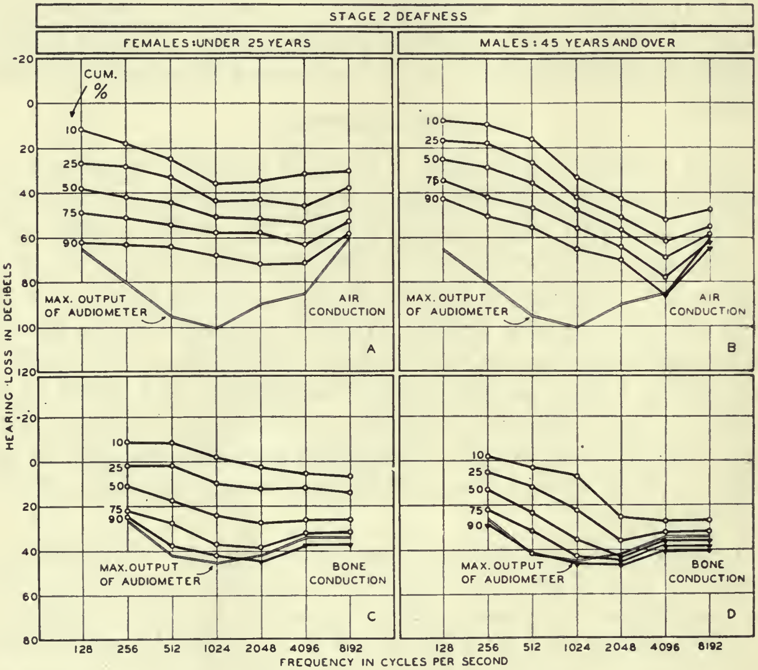

FIG. 6. Percentage audiograms showing characteristic ranges of hearing loss by air and bone conduction for females under 25 years of age, and males 45 years of age and over, having a clinical history of stage 2 deafness.

A trend similar to that shown for stage 1 deafness is again shown for stage 2 deafness. Females tend to have a fairly uniform hearing loss on all tones by air conduction; males have progressively increasing degrees of hearing loss from low to high tones. Cases of stage 2 deafness, for the most part, represent a loss of about 50 per cent of the total normal hearing capacity.

The problem of residual hearing is not acute for these cases. However, because of the fact that there is such a wide variety of hearing

loss patterns which yield a degree of practical handicap corresponding to the definition of stage 2 deafness, it is an extremely difficult

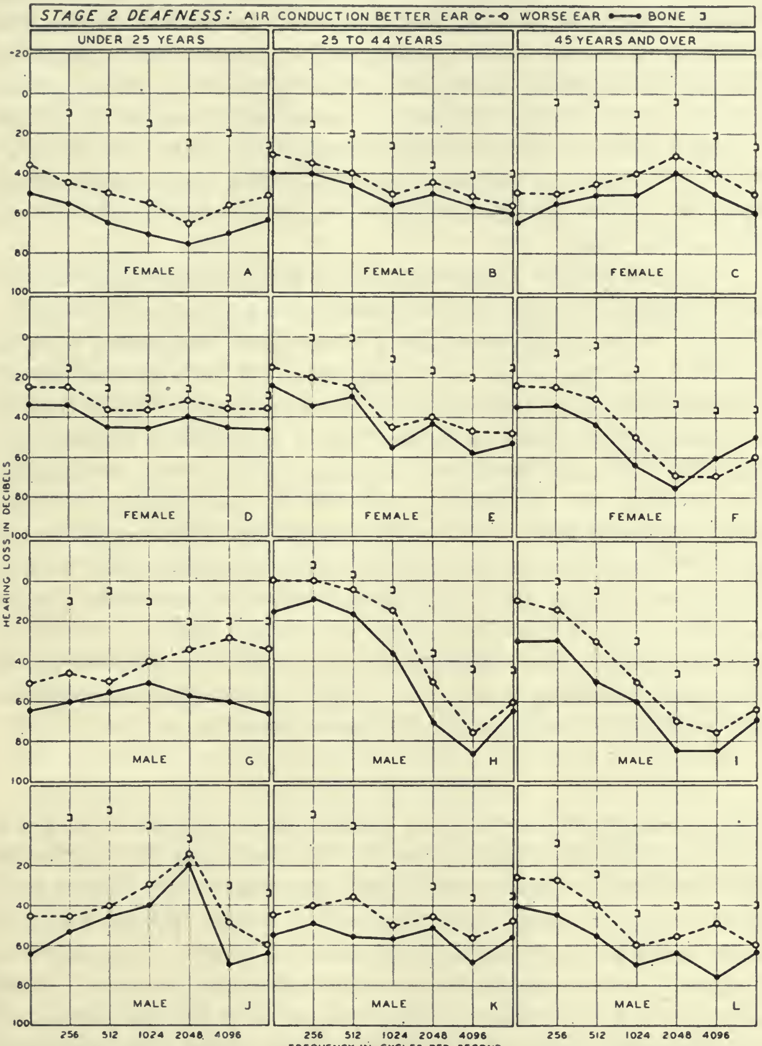

FIG. 7. Individual cases illustrating the various types of hearing losses which occur in stage 2 deafness.

problem to design hearing aids which can rectify all these defects. For the typical female having stage 2 deafness, a hearing aid which

gives uniform amplification to sounds above 500 cycles would give highly satisfactory results if the total gain were 35 to 40 db. For a typical male 45 years of age or over having stage 2 deafness, the amplification gain should be relatively greater for sounds above 1000 cycles and relatively less for sounds below 1000 cycles. The total gain must be somewhat more than in the case of the females and the necessity for eliminating background noises of low frequency is more important, since in most cases these patients have fairly acute hearing for all sounds from 64 cycles up to 256 cycles. Inasmuch as these frequencies play no part in speech articulation, they should be eliminated in the circuit.

Comparison of Figs. 6*A* and 6*C* leads to the conclusion that cases of stage 2 deafness among females under 25 years of age are of two general types: one being essentially a conductive loss ranging from 25 to 45 db by air conduction, with normal acuity by bone conduction; and the second being a uniform type of nerve deafness where the loss by air conduction is in the neighborhood of 50 to 60 db, accompanied by an equivalent loss by bone conduction. A third type, not as prevalent as these two, involves a loss which characterizes males 45 years of age and over. On the other hand, by comparing Figs. 6*A* and 6*B* it is seen clearly that stage 2 deafness among males is fairly homogeneous in type, involving marked nerve deafness of the chronic progressive type. Less than 25 per cent of the males have any usable hearing by bone conduction for tones higher in frequency than 1000 cycles, whereas more than 75 per cent of the females have fairly good hearing by bone conduction on these frequencies.

STAGE 3 DEAFNESS

Cases of deafness in which the impairment is sufficiently severe to prevent perception of speech over the telephone are classified under stage 3 deafness. The majority of persons included in this group have sufficient residual hearing to understand loudly spoken words or speech which has been amplified by artificial means. This degree of impairment is a serious handicap to any kind of employment in which hearing is even a secondary matter and prevents the individual from enjoying music, drama, sound motion pictures, and direct conversation with one or more persons. There are no portable hearing aids on the market at the present time which even approximately satisfy the requirements of most cases of stage 3 deafness. There are several models of nonportable equipment which give definitely satisfactory

performance for some cases of stage 3 deafness. The major difficulty in the way of providing satisfactory portable sets for these persons appears to lie in the large amount of power required and the intricacy and, hence, bulk of the necessary circuit parts that will produce proper selective amplification. As a group, these persons manifest considerable anxiety because they are aware of a highly distorted auditory world and one to which they can not adjust themselves satisfactorily. Persons with somewhat greater aural handicap resign themselves more easily to a world which excludes auditory perception and have less concern about restoring the use of a sensory facility which they once enjoyed. Stage 3 deafness cases are still able to hear, but are not able to perceive speech to any appreciable extent.

Characteristic ranges of hearing loss encountered in stage 3 deafness are illustrated by the percentage audiograms in Fig. 8. Representative individual cases are shown in Fig. 9. Fig. 8*A* shows that more than 85 per cent of the measurements on females under 25 years of age with stage 3 deafness are at a hearing loss level less than 80 decibels. About 70 per cent of the measurements lie between 60 and 80 decibels' loss. Comparison of Figs. 8*A* and 8*B* reveals that the ranges of hearing loss occurring in stage 3 deafness are approximately the same for females under 25 years of age and males 45 years of age and over. A separate tabulation of individual audiograms indicates, however, that an age-sex difference similar in type to that illustrated above for stages 1 and 2 deafness exists also for stage 3 deafness, although such differences occur less often at the stage 3 deafness level. By comparing Figs. 8*C* and 8*D* one notes that males show retention of good hearing by bone conduction for 256, 512, and 1024 cycles more often than the females. These differences are significant from the standpoint of hearing-aid design, since the type of selective amplification that will produce maximal speech articulation must take into account the relative amounts of residual hearing by bone conduction.

TOTAL DEAFNESS FOR SPEECH

Total deafness for speech in the present study was defined as "inability to hear speech under any circumstances, even by means of hearing aids or other types of amplifiers." A second qualification placed upon the definition was that the impairment was acquired after the individual had learned speech in the normal manner. Persons

were classified as deaf-mutes if they had acquired severe deafness before learning to speak.

The distributions of hearing loss measurements on females under 25 years of age and on males 45 years of age and over in the total deafness group are illustrated in Fig. 10. The total loss of hearing for all tones by either air or bone conduction is greater for the younger

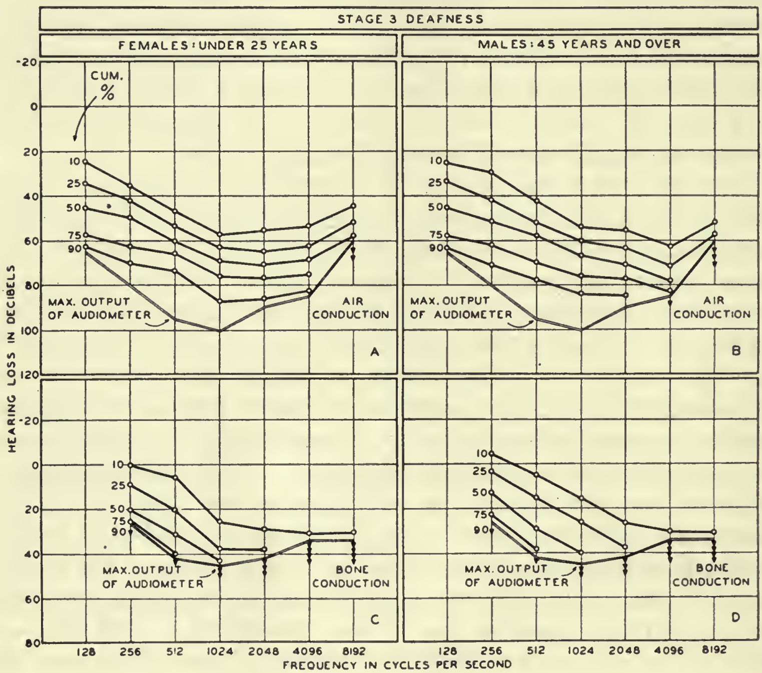

FIG. 8. Percentage audiograms showing characteristic ranges of hearing loss by air and bone conduction for females under 25 years of age, and males 45 years of age and over, having a clinical history of stage 3 deafness.

females than for the older males. This difference in character and degree of hearing loss is consistent with the age-sex differences shown for the three stages of partial deafness.

The inference is drawn from the nature of the residual hearing and from the supplmentary data obtained from the clinical history and the otological examinations that the majority of these severe deafness cases among the older males are advanced stages of chronic progressive nerve deafness, which typically exhibits relatively greater losses for the higher tones.

Total deafness for speech is more uniform in relation to sound frequency among young children and adolescents. It is noted that

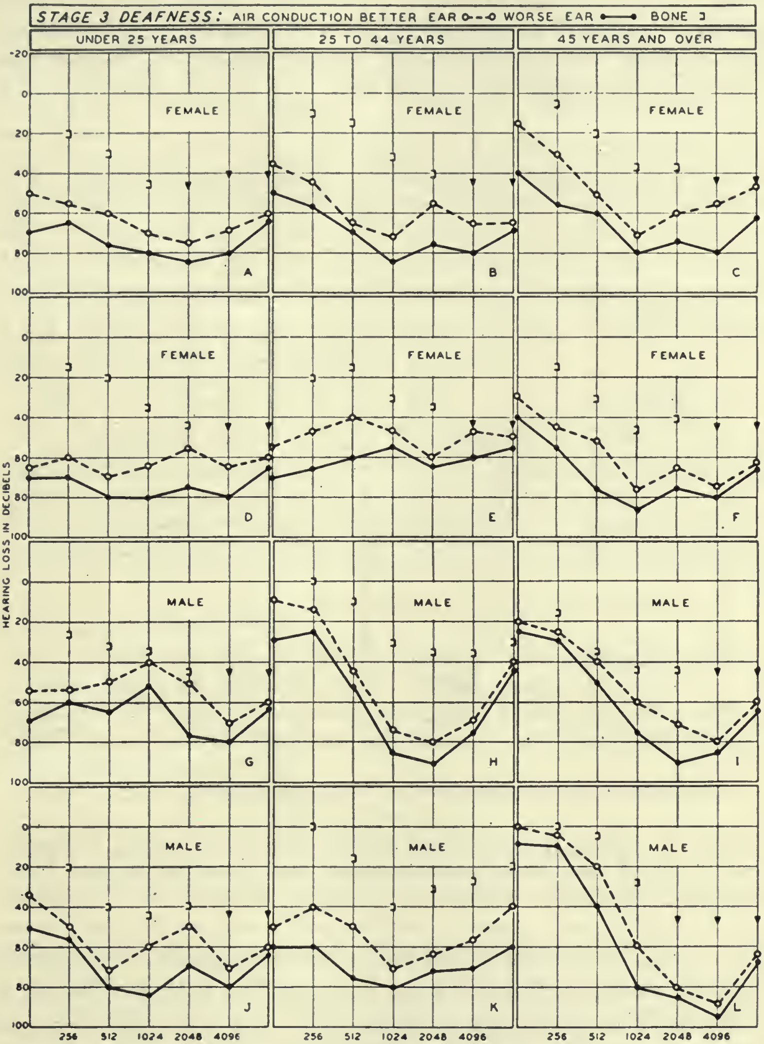

FIG. 9. Individual cases illustrating the various types of hearing losses which occur in stage 3 deafness.

among the older males hearing loss on tones under 1000 cycles is less than 85 db for more than 50 per cent of the cases, whereas for tones

higher in frequency than 1024 cycles about 90 per cent of the males show hearing loss in excess of 80 db. Less than 25 per cent of the people in the totally deaf group are actually totally deaf for speech sounds, but a much greater power level is required to enable any of these people to hear speech with any useful degree of articulation than is available in portable hearing-aid sets. An overall gain of about 65

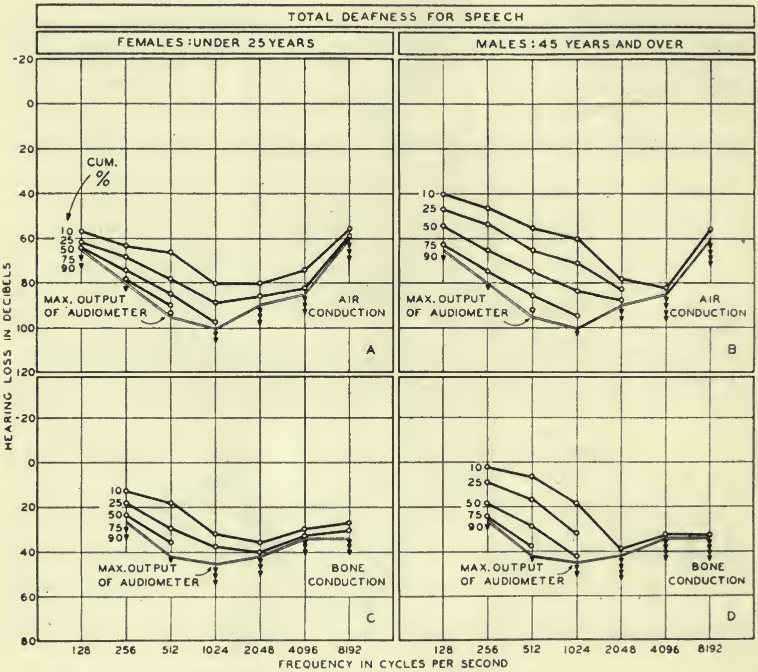

FIG. 10. Percentage audiograms showing characteristic ranges of hearing loss by air and bone conduction for females under 25 years of age, and males 45 years of age and over, having a clinical history of total deafness for speech.

to 70 decibels is required to render the various important components of speech sounds sufficiently loud to enable the deafened listener to understand 50 to 60 per cent of the speech. There are two additional insurmountable difficulties in the way of providing hearing-aid equipment for persons having this degree of auditory handicap. First, normal speech undergoes a wide variation in maximum and minimum power levels from moment to moment. These fluctuations in power level are essential properties of normal speech sounds. In order for

the listener to respond to these variations he must have a range of serviceable hearing to the extent of about 70 db above his threshold values. As the amount of hearing loss increases, the useful range of hearing is narrowed so that the greater the degree of hearing loss, the more restricted becomes the capacity of the ear to respond to this wide range of sound intensities. No type of hearing aid can overcome this limiting factor. Secondly, for persons with marked deafness, sounds which are barely audible may be painfully intense and, hence, the individual can not tolerate continuous stimulation. This difficulty can not be overcome in hearing-aid design. It appears, therefore, that the question of providing artificial aids to hearing for persons having hearing losses in excess of 80 decibels is restricted to the possibility of enabling the listener to hear "guiding" sounds, rather than complete perception of speech.

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REPORT OF THE STUDIO LIGHTING COMMITTEE*

Summary.—*A brief survey of some new technics in studio lighting practice, covering both carbon arc and incandescent lighting.*

Since the Fall Convention of the Society, studio production has been at a relatively low ebb owing to the exigencies of the war situation which has had a profound effect upon the motion picture business. There have, however, been some innovations in the technics of studio lighting which should be reported.

RECENT STUDIO INCANDESCENT LIGHTING EQUIPMENT

(*1*) An improved 5-kw mogul bipost lamp was introduced using a *T64* bulb in place of the usual *G64*. The new shape provides additional bulb volume and removes the glass, at the critical point, farther from the filament so as to prevent blistering. Along with the temperature decrease of the bulb, lamp blackening is markedly reduced so that the effective life of the lamp is considerably prolonged, especially in the case of color-photography *CP* globes for Technicolor use.

(*2*) *R-40* reflector lamps now available in spotlight and floodlight types in both the 150 and 300-watt sizes, as well as a 500-watt photoflood type, are being used by some studios where a small but efficient floodlight is necessary, such as for close-ups, behind set pieces, *etc.* *R-2* reflector photofloods have been used to illuminate the mattes for the process shots in some of the outstanding recent color photography.

(*3*) Daylight fluorescent lamps were introduced to studio lighting technic by several progressive cameramen of leading studios. The high diffusion, freedom from glare, and coolness of these lamps are among the advantages of this equipment, as well as the high actinic value which makes the lamps far more effective than the visible effect would indicate.

Tests made by the Eastman Kodak Company indicate that fluorescent lamps have eight to ten times the effectiveness photographically

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 22, 1940.

as the same wattage of studio type incandescent lamps, which indicates considerable future promise for these sources.

(*4*) Newly developed tubular 3, 5, and 7-kw biplane filament projection lamps are being used for process projection of still backgrounds. In Twentieth Century-Fox's *Everything Happens at Night,* over thirty of the slide backgrounds were illuminated by the 7-kw lamp.

(*5*) Small spotlights using 100 and 150-watt tubular projection lamps were developed by the Warner Bros. Studio. These small spotlights, now commercially available, are used for close-up lighting and where space is at a premium.

CARBON ARC LIGHTING

There have been no basic changes in lamp design, though a number of refinements have been made by the manufacturers of such studio lighting equipment.

A 16-mm. × 22-inch super high-intensity studio positive carbon has been produced which is capable of burning at currents as high as 225 amperes and 75 arc volts. This carbon is finding considerable use in process projection work where the larger source and higher intrinsic brilliancy is needed for adequate screen illumination.

LENS TREATMENT

Surface treatment of camera lenses to increase their transmission and to eliminate internal surface reflection is undergoing a stage of development and initial application. The advantages gained by such lens treatment will undoubtedly in some degree affect the methods of studio lighting. Details of this development are reported in a paper by W. B. Rayton, published in this issue of the JOURNAL on p. 89.

E. C. RICHARDSON, *Chairman*

F. E. CARLSON	R. E. FARNHAM	C. W. HANDLEY
F. M. FALGE		D. B. JOY

DISCUSSION

MR. WILLIFORD: Are the new fluorescent tubes operated on alternating or direct current?

MR. E. C. RICHARDSON: Both. Basic to the operation of those tubes is a hot cathode mercury arc, and since it is an arc, there has to be a ballast medium in the circuit. If they operate on direct current the ballast is a resistance, and if they operate on alternating current it is a reactance. There is a possibility of operating the fluorescent lamp on 3-phase current. With certain of the fluorescent bodies

fortunately there is a delay. The fluorescence does not change much during the arc cycle. In some applications three lamps are used, one in each phase of the circuit, by which a practically uniform and continuous emanation results.

The principal objection to the fluorescent lamp at the present stage is that it is a "soft," non-projectable source. They are good for broadside lighting, and might be very useful for lighting backings. But much photographic lighting has to be done by projectable sources, and there are new sources coming. At a recent meeting of the Pacific Coast Section Mr. F. M. Falge of the General Electric Company gave us a report and demonstration of a large group of developments of his company. About a dozen new lighting mediums, sources and devices, were presented, and of the total number not one existed five years ago.

MR. KELLOGG: How seriously is the 48-cycle lamp being considered?

MR. RICHARDSON: It is not being considered at all, as far as I know. Its possibilities have been known for a long time, but we are confronted with the problem of bucking the existing standardization.

MR. HYNDMAN: The Studio Lighting Committee has about two major functions: One is to report on the progress of studio lighting; and, second, in doing so, to recommend procedures, if possible. At the present stage of the lighting art recommended procedures of lighting would appear to be very difficult, because one has to accept whatever the cameraman believes to be the proper lighting for a given artistic effect. Therefore, it does not fall within the scope of the Studio Lighting Committee to study the quality of pictures. All it can do is to study the conditions, characteristics, and applicability of given light-sources.

MR. CRABTREE: Is the heat problem still serious in the studios?

MR. RICHARDSON: The heat problem is practically negligible today; the increased speed of film has reduced the light intensity in general, and extremely so in black-and-white sets.

The arc lighting for Technicolor pictures has presented no heat difficulties, because the spectrum emanation is principally in the shorter wavelengths.

MR. CRABTREE: Is there any trend away from or toward arc or incandescent lighting?

MR. RICHARDSON: When Technicolor developed the three-color process, back in 1933, they started using arc lighting entirely in their photographic operations since the carbon arc was a source of illumination that was very close to daylight. New equipment had to be designed, because the old arc lighting was a product of the silent picture days, before the recording of sound.

The studios that purchased the modern arc equipment for color purposes very rapidly began to use it in their black-and-white sets. Many cameramen, all through the transition from silent to sound and from orthochromatic through the various stages of panchromatic film emulsions, had always used a considerable amount of arc lighting. There was something they felt they could obtain in the definition and quality of the picture by utilizing arc illumination.

Film speeds are now becoming very high, and for a while we see trends swinging away from arc lighting toward Mazda, and then again the trends reverse. That is due sometimes to styles of photographic taste, because they also change. When one of the cameramen does a job that is recognized as a fine piece of camera work, other cameramen try to gather which way the wind is blowing and try to follow the trend of the public's and the critic's desire.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

NEW LENSES FOR PROJECTING MOTION PICTURES*

W. B. RAYTON**

Since the early days of the industry, motion picture exhibitors have usually been searching for increased illumination. Among the reasons that at various times have led to this demand have been a desire for larger picture sizes, the introduction of perforated screens with a consequent reduction in reflectivity, the use of low key-lighting in the studios, and the growing use of color. The equipment manufacturers have constantly striven to satisfy the needs of the projectionist and the history of their activities consists of a constant series of improvements in sources of light, lamp houses, the optics of the illuminating system, and in projection lenses. This brief paper is offered to put on record two new series of projection lenses which constitute another step in this long record of advancements in equipment design.

Both series are made with a relative aperture of $f/2.0$. It is to be understood that no claim is made that this is the first time that projection lenses with a relative aperture of this size have been made. In fact, lenses of considerably higher apertures have been made, although to what purpose it is difficult to see, if considered for theater projection with an arc lamp as the source of light.

The first series is called the Super Cinephor $f/2.0$. It is available in focal lengths from 2 to 5 inches for use in theater practice. Focal lengths of 6, 7, and 8 inches are also available but can not be used on existing projectors because of the limitations of the lens holder. They are made primarily for use in background projection in motion picture studios. These lenses are anastigmats, which is to say, they are simultaneously corrected for astigmatism and curvature of field. Speaking before this Society in April, 1927,[1] and commenting on a tendency that seemed to be developing at that time of building theaters with short projection distances and large screens, I made the statement that this tendency seemed likely to compel the use of anastigmat constructions in motion picture projection, but that if this result followed, it would be possible only by reducing the relative

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 29, 1940.

** Bausch & Lomb Optical Co., Rochester, N. Y.

aperture of the projection lens or accepting a lower quality of definition over the whole picture area. In spite of this somewhat pessimistic view, in three years we had designed and made available an anastigmat with a relative aperture of $f/2.3$ which was faster than the majority of projection lenses then in use, whose central definition was at least equal to anything in use at the time, and with greatly superior definition at the margin of the field. This was the $f/2.3$ Super Cinephor, undoubtedly the finest lens that had ever been offered up to that time for the projection of motion pictures. Because of its complex construction and the dense barium crown glass used therein, the light transmission was considerably less than that of lenses of the Petzval type commonly in use. In spite of this handicap, acceptance of the lens exceeded our expectations. Nevertheless, we did not feel satisfied to let the matter rest at that point, but continued with experiments looking toward a new design with still greater relative aperture and

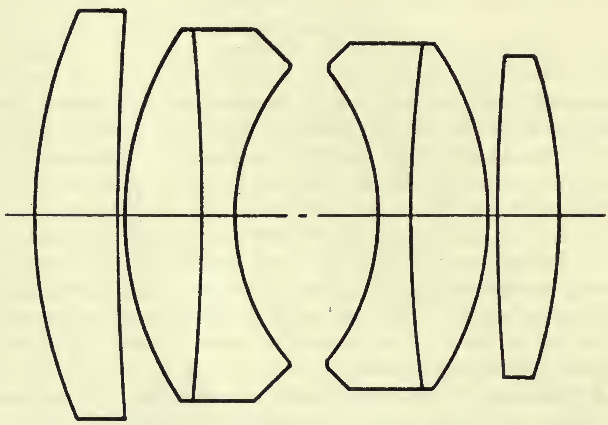

FIG. 1. Super Cinephor 5-inch, $f/2.0$.

employing glass of higher transparency. The result is a lens of the type shown in Fig. 1, in which the crown elements are made of light barium crown glass of high transparency and in which the corrections have been perfected for a relative aperture of $f/2.0$ to such a point that an image of unimpeachable quality over the whole area of the screen is produced.

At just about the time we were ready to announce these lenses, experiments which had been going on in various parts of the country on anti-reflection treatment of glass surfaces[2,3,4] had reached a point where it seemed practicable to incorporate such a feature in the lens in question and thereby obtain a very substantial increase in its light transmission and, consequently, in the brightness of the projected image. Release of the lenses was therefore held up in order to permit the surface treatment to be incorporated. Experiments were conducted in motion picture theaters in order to satisfy ourselves reasonably well as to the durability of the surfaces in service. These experiments seemed to indicate that there was no reason to question their permanence except that the results of the usual method of treatment will not stand the cleaning process as ordinarily em-

ployed on lens surfaces. In order to overcome the possible difficulty offered by this condition, we have gone a step farther and have sealed the lenses air-tight so that they neither need to be taken apart for cleaning nor can they be taken apart except at the factory. This leaves all surfaces completely protected against dust, moisture, and oil vapor, except the outside surfaces. The treatment applied to the outside surfaces is, however, such as to make it possible to clean them in the ordinary manner. Fortunately, the glass employed in the construction is one of the few that permits an effective treatment in this way.

The question naturally arises as to how much increase in illumination may be expected from these lenses. It is impossible to answer this question in such a way that it has a definite meaning for any particular installation. We can make some assumptions, however, and on the basis of those assumptions state what may be expected. If we assume that the basis of comparison is a lens of relative aperture

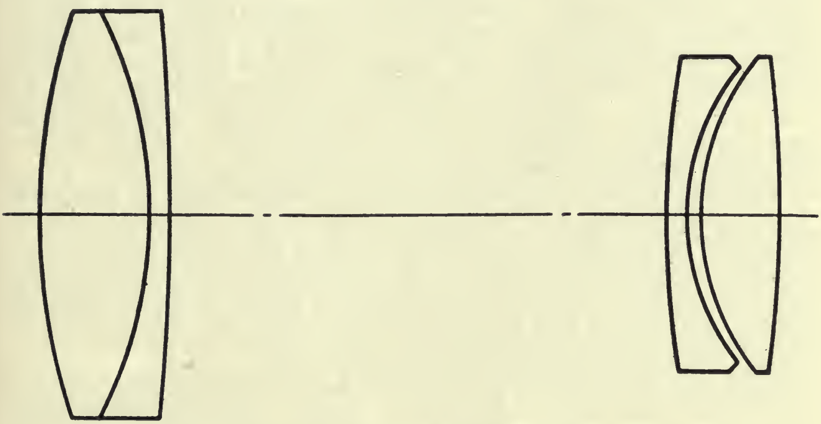

FIG. 2. Cinephor 5-inch, $f/2.0$.

of $f/2.4$, a lens of the same type with a relative aperture of $f/2.0$ will transmit 44 per cent more light, assuming that the aperture is completely filled by the illuminant. The effect of surface treatment is to provide a further increase of illumination of from 25 to 30 per cent.

Because of the fact that it has 8 air-glass surfaces as against 6 in the ordinary Petzval type of projection lens, the light transmission of the $f/2.0$ Super Cinephor will be about 88 per cent of the transmission of the Petzval type of lens such as, for example, the Bausch & Lomb Cinephor lens. If we assume 27 per cent as the average gain in transmission due to surface treatment, then, combining all factors, the treated $f/2.0$ Super Cinephor should show a gain of 61 per cent over an $f/2.4$ untreated lens of the Petzval construction.

This can be realized only if the illuminant is competent to utilize all of the aperture of the lens. Such illuminants do not exist. Some of the high-intensity reflector arcs, however, are competent to utilize a relative aperture of 2.2. As compared to an $f/2.4$, this represents a gain due to aperture of 19 per cent. Com-

bining this with the gain due to surface treatment and the 12 per cent loss due to increased number of air-glass surfaces, the resulting possible increase is still 33 per cent with reference to a Cinephor lens of a speed of $f/2.4$, and at the same time this is accomplished with a flatter field of view.

As to whether $f/2.0$ illuminants are practical, it is not the purpose of this paper to deal. A report was presented to this Society at the 1939 Fall Meeting covering some experiments that had been made in this direction.[5]

In addition to the increase of brightness of the projected image, experience has shown that the surface treatment has a further beneficial effect in the reduction of veiling glare and increasing the contrast of the image. Projectionists who were given experimental lenses for trial unanimously and voluntarily reported increased contrast and apparently improved sharpness of definition. The latter can not result from any actual reduction of aberrations, but must be the effect of improved contrast. It is well known that any stray light on the screen will result in a loss of contrast. In untreated surfaces, light is reflected from each air-glass surface back toward the light-source. Some of this light is again reflected by other surfaces toward the screen. Another fraction of the light reflected back toward the source falls upon the film and by it is again reflected forward and reaches the screen. Both of these result in a certain amount of light appearing in areas that should be black. Reducing the amount of reflection has a very decided effect in improving the general appearance of the projected image.

We believe the lens just described represents the highest point yet achieved in projection lens performance. It combines all the advancements in the art so far developed. Longer focal lengths could be supplied if projection machines were provided with lens holders competent to receive them. Until such changes are made in projectors, however, it is impossible to employ in theater projection lenses with a speed of $f/2.0$ in focal lengths longer than 5 inches. The lens is made in focal lengths from 2 to 5 inches in $^1/_4$-inch steps.

At the same time, a second series of lenses has been designed with a speed of $f/2.0$ of the Petzval type, shown in Fig. 2. In order to maintain good definition with the increased relative aperture it has been necessary to increase the length as compared to the old Cinephor and this leads to a decreased back focus. At the same time it is necessary to maintain such a diameter for the back components as to make it impossible to adapt these lenses to projectors of designs prior to current manufacturing models. This lens was designed to give high speed at the lowest possible price. It is offered, therefore, without the special features that characterize the Super Cinephor: namely, treatment of surfaces and sealing, features that can be added only at a substantial increase in price. The same condition that limits the focal length of the $f/2.0$ Super Cinephor to 5 inches applies also to this case, so that there is no point in making these lenses in focal lengths longer than 5 inches. They are offered in a series beginning with 3 inches and extending to 5 inches, in $^1/_4$-inch steps.

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[5] JOY, D. B., LOZIER, W. W., AND SIMON, R. W.: "Large-Size Non-Rotating High-Intensity Carbons and Their Application to Motion Picture Projection," *J. Soc. Mot. Pict. Eng.*, **XXXIV** (Mar., 1940), p. 241.

DISCUSSION

MR. RICHARDSON: How long do you think the sealed interior surfaces will require no attention?

DR. RAYTON: I can only hazard a guess, based on our experience of one year with such lenses in theater practice, in daily use. These lenses showed no signs of change of the internal surfaces within that length of time. I dare say that the answer to the question depends entirely upon the durability of the seal, and I suppose in the course of time that material may break down and permit the lens to begin to pump air. It seems to me that it is safe to hazard a guess that that will not happen in less than five years—maybe ten years.

MR. KELLOGG: What is the magnitude of absorption in the glass?

DR. RAYTON: In optical glass it is half a per cent per cm, and from that on up to 2 per cent in glasses still usable in optical instruments. In other kinds of glass —window glass and the like, it can, of course, reach very much higher figures.

MR. RICHARDSON: Mr. W. C. Miller tells me that in lenses treated for camera work an unexpected phenomenon was found. In photography there appears to be an advantage beyond the apparent improvement in transmission. Untreated lenses producing flare apparently put an overall fog upon the emulsion of the film, upon which the photographic image has to be superimposed, and apparently the film must be unduly exposed to superimpose the image upon the fog so produced. Is that explanation valid? I am interested to see whether or not in projection we have been having a similar situation on the screen.

DR. RAYTON: Both in projection and in photography, I think the answer is yes. With a projected image of good contrast, a better subjective reaction is obtained with a lower level of illumination than with a higher level of illumination, if the contrast is poor. I have seen examples of photography done with these lenses that seem to prove Mr. Miller's point, although it is not a factor that can be expressed quantitatively. Personally, I am leaving it out of consideration in any quantitative statements in connection with projection. It is a factor of real significance, but I do not know how it can be measured quantitatively.

MR. FARNHAM: I believe that the average surface loss is 4 to 5 per cent. To what value does this treatment bring it?

DR. RAYTON: Actual surface loss may run to higher than 5 per cent. It depends upon the index of reflection of the glass; 5.5 per cent is sometimes given. Some lenses average 5.5 per cent loss per surface. The reduction of reflected light, by evaporating films on the surface can reach, I should say, a figure of three-quarters of the originally reflected factor. Perhaps it is not too much to assume that it can be reduced to 1 per cent per surface. That is perhaps a little optimistic, but for convenience and calculation it is fair enough.

There is a tendency in some of the literature to be a bit over-optimistic with respect of the gain in transmission. Please bear in mind that it would be utterly impossible to gain something under the circumstances that is not taken away in the first place. If we have a lens system whose maximum loss, due to reflection, is 30 per cent, it is absurd to say that the transmission of the lens can be increased 50 per cent by any surface treatment, because we should have to reduce the light lost by reflection by more than 100 per cent.

MR. C. TUTTLE:* In a paper which Dr. Jones and I published in the TRANSACTIONS of this Society in 1926, we discussed the magnitude of the screen image contrast reduction resulting from projection lens flare. The total amount of this effect is dependent in a marked degree upon the overall density of the picture—the more transparent the frame, the greater the contrast reduction. Though the effect occurs in the most noticeable degree in the shadow region of the picture, it also influences the whole tone reproduction curve in a manner somewhat similar to that produced by a reduction of positive gradient by lowered release print development. The data which we then presented, coupled with data on average release print densities which I presented in the JOURNAL in May, 1936, led to the conclusion that, on the average, a flareless lens system might be expected to yield a screen image in which the gradient of the reproduction curve would be from 15 to 20 per cent higher than that of a system with the usual amount of flare.

This point, by itself, is worthy of consideration by the release-print laboratories, since it is obvious that if a given print is to be projected through one of these treated lenses in one case, and through an untreated lens in another case, the variation in contrast resulting from the single uncertainty would be as great as or greater than the contrast variation from print to print, according to the development-tolerance standards now in effect in the release-print laboratories.

Another and probably more important aspect of the effect of lens treatment is its possible influence upon the Society's recommendations of screen brightness.

In 1936 the Screen Brightness Committee recommended 7 to 14 foot-lamberts. This recommendation was later accepted by the Standards Committee and adopted into the "Recommended Practice" sections of the Society standards.

The value of 7 foot-lamberts was considered as possibly too low for a low limit, but it was selected by the Committee because it was the highest value which could be obtained with the best of the then-existing equipment on large screens, *e. g.*, 30 feet wide.

Now Mr. Rayton gives us hope of a 30 per cent increase in efficiency of putting light on the screen. I call to the attention of the Standards Committee that the reason for the value 7 no longer exists; perhaps it should be changed to 9.

The Screen Brightness Committee fixed on the *upper* value of 14 on the basis of what it considered to be an allowable variation of the apparent quality of the picture as a function of the brightness change. This matter is discussed in the committee report published in August, 1936.

The contrast-seeing ability increases with brightness—this change being approximately 15 per cent for a doubling of brightness. Thus, as treated lenses come into use, *two* distinct effects tend to increase the screen-image contrast—

* Communicated.

the first resulting from a decrease of flare, the second from the increase of brightness.

It appears to me that if, as argued by the Screen Brightness Committee, the allowable variation in apparent image contrast is to fix the screen brightness tolerance, then it follows that the introduction of treated projection lenses should decrease the screen brightness tolerance. For some time both treated and untreated lenses will be in general use, and it is probably not a good idea to recommend new practice standards of 9 to 18 foot-lamberts because if release-print contrast is adjusted to look right at 9 foot-lamberts with an untreated lens, a given print will then have too high contrast if projected at 18 foot-lamberts with an untreated lens.

At a guess, a reasonable recommendation to fit present conditions would be 9 to 14 or 15 foot-lamberts.

MR. WELMAN: The earlier $f/2.3$ Super Cinephor was not a Petzval lens, was it?

DR. RAYTON: No.

MR. WELMAN: You made your comparison of 30 per cent by comparing the new lens with the Petzval $f/2.4$. What would be the comparison of this lens with the earlier Super Cinephor of 2.3?

DR. RAYTON: The product of the three factors that I mentioned as contributing to increased illumination at the maximum brought us to a value of 61 per cent, comparing the new Super Cinephor against the old $f/2.4$ Cinephor. Compared with the old Super Cinephor you would add another 10 or 12 per cent.

MR. MAURER: A great deal of what Dr. Rayton has told us is of decided interest in the 16-mm field. The comment has often been made to me by competent observers that the quality of the lenses in general use for 16-mm projections leaves a great deal to be desired. It is generally, and I think somewhat erroneously, assumed that 16-mm equipment must be held down to low cost in *all* its components. As a result, sometimes we find what I feel to have been unnecessary and undesirable sacrifices of quality in overall results.

With that in mind, I should like to ask Dr. Rayton, not with a view to accuracy, but just as to the general order of magnitude, what are the comparative costs of the Anastigmat Super Cinephor construction and the Petzval type of construction commonly used for 16-mm projection lenses?

DR. RAYTON: Between perhaps 5 and 10.

MR. KELLOGG: If you look back toward the projector in a theater, you see an impressive amount of light coming from the lens surface, and also from the light-beam, due to scattering by the dust in the air, or smoke. I wonder whether the light scattered in this manner is much of a factor in making haze on the screen. Also, how much of the light scattered by the lens surface may be due to dust and scratches? These specks look intensely brilliant when you look at the lens from close by.

DR. RAYTON: There is no doubt that dust on lens surfaces is responsible for considerable diffusely distributed light. It is not so bad that every last speck of dust has to be removed, or that one should worry about every little scratch that appears on a lens surface. Nevertheless, many lenses are used in a condition that is practically criminal, from the standpoint of the quality of the image.

MR. ROBERTS: What is the relative efficacy of the two treatments used in the

Super Cinephor; or, what is the difference between the coating used for the inside surfaces, which I understand is a relatively perishable coating, and the external treatment which can be handled a little bit more roughly?

DR. RAYTON: We can only answer the question for the particular kind of glass employed in this construction. Whereas the applied coating can produce an effect equivalent to reducing reflection to one-quarter of its original value, the other method used on the external surfaces reduces it to one-half its original value. The difference between the two methods, if applied to the external surfaces, will affect the transmission of the lens perhaps 5 per cent.

MR. ROBERTS: Can the outside treatment be applied to eye-glasses?

DR. RAYTON: It can not be employed on the glass ordinarily used on eye-glasses.

MR. HOVER: I suspect there will be many projectionists who will worry about the sealing of the lens. We might remember that some of us have the better grade of optical systems in the sound mechanisms and those lenses are sealed. I have one pair, of excellent make, that has worked a little over five years, without any difficulties whatever, and I believe that the optical system in the sound mechanism frequently (the rear of it, at least) operates at a rather high temperature.

MR. KURLANDER: What is the absolute transmission constant of the Super Cinephor lens having eight air-glass surfaces, treated and untreated?

DR. RAYTON: Approximately 65 per cent for the untreated lens, and from 80 to 85 per cent for the treated lens.

MR. FRANK: The $f/2$ Super Cinephor lens can be used only in the current models of projectors, such as the Simplex, the Super Simplex, and the *E-7*. By modifying the lens holders of the older models, which the manufacturers are prepared to do at a reasonable cost, these lenses can be used with them. I am a little uncertain, however, concerning the statement you made as to whether the same thing is true in the case of the $f/2$ Cinephor lens, or whether I am to interpret your statement as meaning that under no conditions can the $f/2$ Cinephor be used with the older model of the Simplex projector.

It should be pointed out also that the old Series *2* Cinephor lenses are available only with treated surfaces, and the less expensive type, as heretofore, without treated surfaces, is no longer manufactured.

MR. SCHEICK: Any of our lenses can be supported without any unusual adaptors in the Super Simplex and the *E-7* Simplex. But in the old standard Simplex mechanism it will be necessary to use the special adaptor you have built called the *62-C*, which will support any of the lenses whatsoever in that mechanism.

MR. KURLANDER: What is the method of sealing employed?

DR. RAYTON: It is the same type of sealing that has been used successfully in the sound reproducer—the use of a gasket and a material that is oil-proof and maintains its elasticity indefinitely.

MR. PALMER: One point discussed at the Atlantic Coast Section Meeting, at which the coated lenses were demonstrated, was whether there is a color difference in the light projected through coated and uncoated lenses.

DR. RAYTON: Undoubtedly there is a difference, just as there is a color difference in the light reflected from ordinary glass surfaces. The question is probably inspired largely by the fact that the appearance of these treated surfaces is de-

cidedly colored. However, when you stop to think that the amount of light reflected from them only amounts to, say, 1 per cent of the incident light, any selectivity in that 1 per cent ceases to have much significance. If there is selectivity in the 1 per cent, there is the same selectivity, or the complement of it, in the transmitted light. Undoubtedly, if sufficiently precise measurements had been made spectrophotometrically, there is a change in the color of the transmitted light. That can be controlled to a considerable extent in the applied process. That is one of the factors that has to be watched in the practical application of the treatment, and careful attention is given to it. I do not think that, controlled in that way, the results can create any color disturbance of any significance.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

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18 (May, 1940), No. 9

Stereophonic Reproduction from Film (pp. 260–265) — HARVEY FLETCHER

British Journal of Photography

87 (April 19, 1940), No. 4172

Progress in Colour (pp. 192–194)

Educational Screen

19 (May, 1940), No. 5

Motion Pictures—Not for Theaters (pp. 193–197) — A. E. KROWS

Electronics

13 (May, 1940), No. 5

Photoelectric Tape Recording (pp. 16–18)

Enhanced Stereophonic Recordings Demonstrated by Bell Laboratories (pp. 30–31)

13 (June, 1940), No. 6

Television Receivers Using Electrostatic Deflection (pp. 16–19, 89) — T. T. GOLDSMITH, JR.

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13 (May, 1940), No. 147

Improved Materials for Fluorescent Screens (p. 236)

Institute of Radio Engineers, Proc.

28 (April, 1940), No. 4

The Gradation of Television Pictures (pp. 170–174) — H. E. KALLMANN

International Projectionist

15 (April, 1940), No. 4

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The Influence of Sound Accompaniment on the Dramatic Value of Pictures (pp. 20–21)

Regeneration and Preservation of Film (p. 22) — A. KALIX

15 (May, 1940), No. 5

Fundamentals of Theater Acoustics (pp. 7–8, 11) — J. E. VOLKMANN AND K. C. MORRICAL

Pro and Con Views of the Switzer Electronic Carbon Arc Control (pp. 12, 15, 16–17) — F. L. HILL AND G. SWITZER

Optical Society of America, Journal

30 (May, 1940), No. 5

The Carbon Arc as a Radiation Standard (pp. 189–194) — H. G. MACPHERSON

1940 FALL CONVENTION

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Headquarters

Headquarters of the Convention will be the Hollywood Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Daily hotel rates to SMPE delegates will be as follows (European Plan):

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00–14.00
Parlor suite and bath, 2 persons	12.00–16.00

Room reservation cards will be mailed to the membership early in September, and should be returned to the Hotel immediately to be assured of satisfactory accommodations.

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	*Railroad Fare* (*round trip*)	*Pullman* (*one way*)
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	135.00	23.65
Detroit	106.75	19.20
New York	135.00	22.85
Rochester	124.05	20.50
Cleveland	111.00	19.20
Philadelphia	135.00	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips. Arrangements may be made with the railroads to take different routes going and coming, if so desired,

but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems. Technical sessions will be held in the *Blossom Room* of the Hotel. Several evening meetings will be arranged to permit attendance and participation by those whose work will not permit them to be free at other times. The Local Papers Committee is collaborating closely with the General Papers Committee in arranging the details of the program.

Studio Visits

The Local Arrangements Committee is planning visits to several studios during the Convention week. Details will be announced in the next issue of the JOURNAL. Admittance to the studios will be by registration card or Convention badge only.

New Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore Rooms* of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the General Office of the Society at the Hotel Pennsylvania, New York, N. Y.

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, October 23rd, in the *Blossom Room.* A feature of the evening will be the annual presentations of the SMPE Progress Medal and the SMPE Journal Award. Officers-elect for 1941 will be announced and introduced, and brief addresses will be delivered by prominent members of the motion picture industry. The evening will conclude with entertainment and dancing.

The Informal Get-Together Luncheon will be held in the *Florentine Room* of the Hotel on Monday, October 21st, at 12:30 P. M.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. L. L. Ryder, *hostess*, and the Ladies' Committee. A suite

will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; Beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the West, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

W. C. KUNZMANN,
Convention Vice-President

SOCIETY ANNOUNCEMENTS

1940 FALL CONVENTION AT HOLLYWOOD

The next Convention of the Society will be held at the Hollywood Roosevelt Hotel, Hollywood, Calif., October 21st–25th, inclusive. Details of the Convention are presented in a preceding section of this issue of the JOURNAL, and further information regarding the papers program will be published in succeeding issues.

All persons wishing to present papers at the meeting should communicate immediately with the General Office of the Society at the Hotel Pennsylvania, New York, N. Y.

PACIFIC COAST SECTION

At a meeting held on June 17th at the Paramount Studio Theater in Hollywood, Calif., Mr. W. C. Miller of the Vard Mechanical Laboratories, Pasadena, Calif., discussed the treatment of lenses for decreasing the reflection of light from the lens surfaces. This was a re-presentation of Mr. Miller's paper originally presented at the Atlantic City Convention of the Society in April, entitled "Speed Up Your Lens Systems."

"The Application of Lens Surface Treatments to Sound Optical Systems," was discussed by Dr. J. G. Frayne of Electrical Research Products, Inc., and C. M. Batsel of the RCA Manufacturing Company.

The meeting was concluded by showing of a picture produced by Messrs. R. B. Atkinson and S. P. Solow entitled "The Alchemist in Hollywood."

THE EXPANDED PROGRAM

OF THE

RESEARCH COUNCIL OF THE ACADEMY OF MOTION PICTURE ARTS AND SCIENCES*

DARRYL F. ZANUCK**

Due to the success of the past efforts of the Research Council of the Academy of Motion Picture Arts and Sciences, the Council is appointing new Basic Committees in the fields of photography, sound, optics, laboratory, and cine-technical

* Extract from address at a general conference held at Hollywood May 29, 1940, for the inauguration of the Research Council's new Basic Committee organization.

** Chairman of the Research Council.

development. These new Committees will multiply the past benefits resulting from the Council's activities and will return the utmost value to the industry from these efforts.

Before going into the details of the operation of these new Basic Committees, a short historical background of the Research Council may be of interest. The Academy of Motion Picture Arts and Sciences was originally organized in 1927, for the principal purposes of advancing the arts and sciences of motion pictures and fostering coöperation among the leadership of the motion picture industry for cultural, educational, and technical progress.

Within the Academy the motion picture industry has set up its Research Council, the entire purpose of which is the "scientific advancement of the motion picture industry through coöperative research, investigation, and development of equipment, practices, technics. Also the promotion of the interchange of ideas and information as pertaining to the motion picture industry; the furtherance of professional and vocational education of motion picture technicians; and the dissemination of information throughout the world by means of conferences, meetings, and publications."

The Academy Research Council is concerned with projects involving investigation beyond the facilities of any individual studio and which can be handled more efficiently and more economically by coöperative effort.

The Academy Research Council is responsible for all matters of standardization on behalf of the motion picture studios, coöperating with the various equipment manufacturers and supply companies and coördinating its activities with the standardization activities of the Society of Motion Picture Engineers, and the Sectional Committee on Motion Pictures of the American Standards Association.

The newly appointed Basic Committees will direct the coöperative conduct of all projects in their respective fields. Each of the Committees consists in general of a representative from each of the studios sponsoring the Council, thus giving each producing company the benefit of the efforts of the best technical personnel in the industry.

The responsibility for the policies and the general direction of the whole coöperative program is in the hands of the Research Council, the membership of which also consists of one representative from each of our sponsoring companies. It is intended that the Chairman of each of the Basic Committees shall serve as *ex-officio* members of the Council and will thus assist in its deliberations.

Each Basic Committee will appoint as many Subcommittees as may be necessary to conduct the various projects in each field, and will be responsible for the coördination of the work of all these Subcommittees.

All Basic Committees will immediately survey their entire field and inaugurate such investigations which the Council, in consultation with the Committee Chairmen, may deem advisable. Many problems brought to the Council's attention since the original announcement of the expanded activities will also be transmitted to the proper Basic Committees.

Facilities of all the studios are of course available to the Council and its Committees. As in the past, it is anticipated that the equipment companies will actively coöperate in the work, continuing to offer and give of their time and facilities as needed to further the Research Council program.

The expanded Research Council will provide a smoothly operating and efficiently functioning organization, capable of immediately handling all problems coming within its scope. The entire plan of operation is founded upon the recognition of the value of careful judgment based upon an orderly study of all the facts.

In practice the following procedure will be followed: A new project or an existing problem may be brought to the attention of the Research Council by anyone connected with the motion picture industry. The problem will then be given consideration by the Council, to decide to which one, if any, of the Basic Committees it will be referred. The Basic Committee will then lay out a program for investigation and either handle the problem itself, turn it over to one of its existing Subcommittees, or set up a new Subcommittee specifically for consideration of this problem.

After thorough investigation and study of the project, the Subcommittee will make its report to the Basic Committee which will then report its recommendations to the Research Council. The Research Council will determine final disposition of the matter.

If the subject of the report is of industry-wide interest it may be published for general circulation, or if of specialized interest to only a small group within the industry it may be distributed upon a restricted basis to only those interested in that particular subject.

The Committees may be as compact and as streamlined as is consistent with proper operation, inasmuch as the Research Council and the Basic Committees, with their representation from all participating companies, will provide a broad, overall, industry viewpoint and supervision.

BASIC COMMITTEES

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General direction of the entire program will be in the hands of the Research Council, the membership of which consists of one representative from each studio sponsoring the Council, in addition to the Chairman, as follows: John Aalberg, RKO Radio; Bernard B. Brown, Universal; Farciot Edouart, Paramount; E. H. Hansen, 20th Century-Fox; Nathan Levinson, Warner Brothers; John Livadary, Columbia; Thomas Moulton, Samuel Goldwyn; Elmer Raguse, Hal Roach; Douglas Shearer, Metro-Goldwyn-Mayer; and Gordon S. Mitchell, Manager.

JOURNAL
OF THE SOCIETY OF
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THE CONTROL OF SOUND IN THEATERS AND PREVIEW ROOMS*

C. C. POTWIN**

***Summary.**—Acoustical science can now be applied to better advantage than ever before in the planning of modern motion picture theaters. A broader understanding of the purposes and principles of acoustical design and treatment is needed, however, to make this application universal. The Society is in a position to do much toward fulfilling this need.*

Greater attention should be given to the design and development of the basic theater structure. The shaping of surfaces for the control of sound reflections is effective and can be kept within a desirable architectural limit. Furthermore, such shaping can be made to function successfully if the basic design is developed to control reverberation.

The all too prevalent idea that "the more acoustical material used, the better the results" should be discouraged. Acoustical materials can be used more efficiently if they are distributed asymmetrically with due regard to the geometry of the reflecting surfaces. In general, they should not be concentrated in large compact areas on single surfaces. This principle of treatment and its effect upon the acoustical characteristics of theaters is discussed.

Instrumental measurements of the effect of surface parallelism upon the frequency reverberation characteristic of a rectangular room are shown. The results are of particular interest with respect to the acoustical treatment of preview rooms.

A principal unit of the sound transmission system in motion picture theaters can now be efficiently controlled. This unit is the path through which sound travels from the loud speakers to the ears of an audience—in other words, the auditorium—the most expensive single unit of the sound transmission system.

In 1929 and 1930, when between 50 and 100 theaters were being equipped for sound every week, it was often difficult to convince exhibitors of the need for good acoustics. Sound was considered a novelty by some; to others good acoustics meant too little to come within the sphere of practical necessity. It was not long, however, before the novelty wore off and efforts were made to improve sound quality in theaters. The exhibitor, sharing in these efforts, began

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received June 8, 1940.

** Electrical Research Products, Inc., New York, N. Y.

seriously to consider improving the acoustical conditions of the important transmission link that he furnished.

Corrective materials were installed in many existing theaters. The significant point, however, is that a number of new theaters were built without consideration of acoustics and were admittedly not so successful as many of the older theaters that had been corrected. This led to the rather general belief that sound absorption quantitatively was the only factor in acoustical planning. Architectural practices were therefore developed that resulted in the installation of excessive amounts of corrective materials. These practices are still being followed to a very large extent in theater planning. They should now be reversed, and theaters should be shaped fundamentally for good acoustics.

Experience has proved that uneven or irregular surfaces, if properly designed, contribute basically to good acoustics. The idea that such surfaces have a definite effect upon sound is by no means a new theory. As early as 1910, Professor Wallace Sabine recognized their value.[1] He pointed out that a coffered ceiling tended to break up or disperse sound, and that if the coffers were varied in size and depth they would have an even greater effect. His early findings established a basis for recent developments and refinements in the use of acoustical form.

One may wonder why we continue to stress the importance of acoustical shaping for theaters. Its value is reiterated only because the results achieved are superior to those obtained through the use of excessive amounts of absorbing materials. Proper shaping reduces room resonances by distributing the eigentones and permits a greater proportion of the reflected sound to be absorbed in the audience area.

It is interesting to note that several of the very best theaters in New York do not have one square-inch of absorbing material on the walls or ceiling. In these theaters, surfaces designed to conform with architectural styles of the past are so ornate and consequently so irregular in form that they effect a rapid dispersion or scattering of sound reflections. No doubt many theaters throughout the country, both of large and small seating capacities, fall into this class.

Present trends in design are toward the use of simple interior treatments, involving little or no ornamentation. The large plain surfaces characteristic of these modern designs tend to produce echoes and allow sound to be reflected many times before it dies away to inaudibility. Acoustical shaping, based on the development of wall

contours rather than on the use of ornamentation, controls these reflections and obviates the need for excessive sound absorption to accomplish a similar effect. Architects tell us that this shaping not only

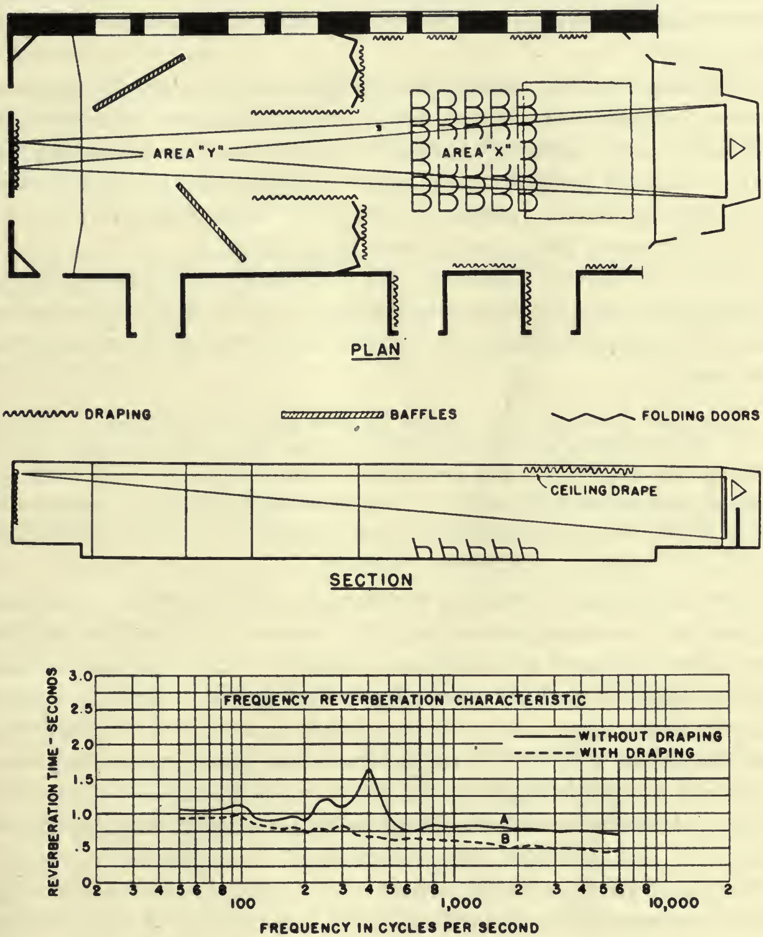

FIG. 1. Example of undesirable effect of plane parallel surfaces.

affords a basis for functional interior design in many instances, but can often be blended very well with modern decorative treatments.

Fig. 1 is an example of the undesirable effect of plane parallel surfaces upon the acoustical characteristics of a rectangular room used for sound pictures. Considering the proportions of this room as a

whole, the length was somewhat excessive and the ceiling height too low. Sliding doors were standard equipment for the room, and inasmuch as the group to be accommodated would not exceed 35 persons, it was decided to close these doors partially in order to reduce the apparent volume, leaving an opening only large enough for projection of the picture.

The coupled room effect[2] which might have produced a feedback of reverberation from area Y behind the opening was minimized by the use of sound-absorbing baffles of rock wool and heavy draping material, arranged as shown in the figure. Measurements indicated that with the acoustical baffling in place no undesirable interference phenomena were encountered from this section.

The next and most significant part of the problem was the acoustical treatment of area X, the listening space. There were three obvious defects contributing basically to poor acoustics within this half of the room:

(*1*) The space was generally too live for good sound reproduction.

(*2*) The excessively low ceiling produced an acoustical image, or gave the illusion that sound originated at a point on the ceiling in front of the screen; and

(*3*) A flutter-echo effect, caused by repeated sound reflections between the ceiling and floor, was so severe that it gave a ringing tone to speech and distorted sound from the reproducing system.

The architectural design of the room limited acoustical treatment to the use of draping materials. The amount required for the flat wall areas was predetermined and installed. This tended to reduce the reverberation, but accentuated the flutter-echo. Acoustical measurements were made to determine the nature of the flutter-echo and the extent to which the additional sound absorption required to overcome this effect might be limited to small areas in order to avoid an over-damped condition. The results are shown on the graph in Fig. 1.

For the measurements the sound source was positioned on the stage and the microphones were placed in the seating area. Curve A (Fig. 1), taken with the draping material installed on the walls but without draping on the ceiling, shows a sharp peak at 400 cps caused by the flutter-echo. A rug with heavy lining material placed on the floor in front of the seats and covering a part of the area under the seats had practically no effect upon the 400-cycle peak.

A drape hung in a horizontal position one foot below the ceiling, at a point between the seating area and the stage, gave the result

shown as curve B (Fig. 1). Here the 400-cycle peak is eliminated, but there is now excessive absorption at the high frequencies. Obviously, the ideal material for the ceiling treatment would be one having its maximum absorption at about 400 cycles. Yet with such a material the acoustical image caused by short-path reflections from the ceiling would still persist.

A fabric with a quilted backing and a hard surfaced facing was finally selected as most suitable. It damped out the low-frequency peaks and gave back a part of the desired liveness at the high frequencies.

The significant points in this analysis are:

(*1*) If the ceiling had been designed out of parallel with the floor, the flutter-echo would not have been produced.

(*2*) By proper shaping of the ceiling, the reflections causing the acoustical image could have been either dispersed or directed away from the listening areas where they proved annoying.

(*3*) On this basis, excessive absorbing material would not have been required to correct these defects.

Admittedly, this represents an extreme case so far as the theater is concerned. The ceiling and floor are not usually parallel in theaters, and upholstered seats covering practically the entire floor area help both to break up and to absorb sound in the vertical plane. For this reason the example is perhaps more directly comparable to the average preview room, where only a part of the floor area is normally used for seating and the problems of room resonance and control of discrete reflections are sometimes even more critical than in the theater.

The ceiling-to-floor condition, however, is comparable to parallel walls in the theater, where one or more frequencies may be accentuated by multiple reflections occurring between these surfaces. If the ceiling of the theater is completely treated and the side walls are neither acoustically shaped nor treated, the flutter-echo may occur between the walls and may be accentuated in the same manner as the ceiling-to-floor condition was in this example.

The type of irregular surface most desirable for use in breaking up or distributing sound reflections in a theater or preview room depends upon the angles and position of the walls, the ceiling, and the seating area, as seen from the source of sound. The shaping may follow a number of different forms, all of which can be developed for artistic value. Angular and splayed forms, carried vertically from the

floor or from a suitable wainscot to the ceiling, have been most often used in the past. Experience indicates that convexly curved forms and angular or splayed surfaces running horizontally instead of vertically, or combined with vertical shaping, can also be used with equally successful results.

A projection of 1 inch to the running foot is sufficient in most cases for the design of angular or convex surfaces. Sharp angles, developing pockets, are not only too severe architecturally but frequently produce resonant cavities.

When angular forms are used, the points of projection should be directly opposite one another on facing surfaces. Otherwise it may happen that the sides of two opposite angles will actually be parallel.

Where a rear wall or a balcony edge is sloped or otherwise shaped to prevent echoes, a projection of more than 1 inch to the running foot is usually required. In these cases the shaping should be planned so that the first reflection from a point at the extreme upper edge of the surface strikes the audience at a distance preferably not greater than 25 feet in front of the reflecting surface.

In connection with the design or remodelling of theaters and preview rooms having low ceilings it is often possible to shape the ceiling so as to create an acoustical effect of increased height. If this shaping is carefully plannned architecturally a similar visual effect may also be obtained.

The question frequently arises, "Is it possible to design a modern theater for optimum hearing conditions without using acoustical materials?" This can be done if the theater is shaped originally so that multiple reflections are eliminated, discrete reflections of high intensity do not reach the audience area too quickly, and the formation of echoes is prevented. However, proper shaping alone is not enough. Fundamental consideration must also be given to the factor of limiting cubic-foot volume per seat in design.

Fig. 2 shows desirable limits of cubic-foot volume in relation to seating, for modern theater auditoriums, based upon controlling sound reflections by internal surface shaping. These limits have been developed as a result of empirical practice, and assume (*1*) the use of upholstered seats with a spring or rubber cushioned bottom and padded back, (*2*) fully carpeted aisles, and (*3*) furred construction of walls and ceiling for low-frequency absorption.

The broken curve is considered generally from past experience to be a maximum practical limit for the auditorium structure. In most

cases a small amount of acoustical material properly distributed will be required for these larger volumes. Cubages in excess of this limit are rapidly leading away from rather than toward economy in auditorium design.

In planning for the control of cubic-foot volume, it is usually more difficult to deal with single-floor houses than with those having a balcony. This can readily be understood from the fact that in the balcony house a greater amount of structural break-up is provided, to begin with, at the rear of the auditorium. However, there are

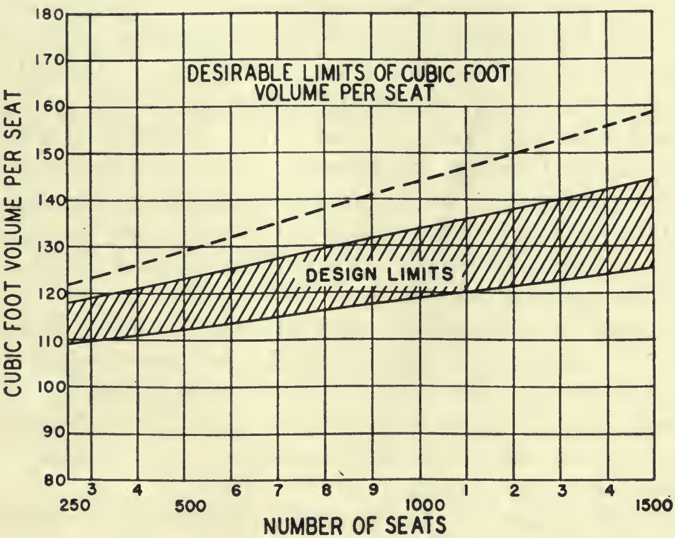

FIG. 2. Desirable limits of cubic-foot volume in relation to seating, based upon control by internal surface shaping.

possibilities in the acoustical design of modern single-floor houses that have not yet been developed. For example, ceilings that slope or step down rather abruptly at the rear and sides, and walls that converge slightly toward the rear, offer means of controlling cubic-foot volume and reducing rear wall area in design.

Since the time of reverberation at various frequencies is related directly to cubic-foot volume and to quantity and quality of sound absorption, it seems advisable at this point to discuss briefly the amount and the frequency characteristic of the reverberation desirable for motion picture theaters. There is nearly universal agree-

ment among engineering groups as to the desirable time of reverberation at 512 cycles per second. Curve *A* in Fig. 3 is based upon our experience, and shows desirable reverberation times in relation to volume at this particular frequency.

The desirable times of reverberation for frequencies below 512 cps require further study. The optimal frequency characteristic derived from theoretical considerations by MacNair[3] and shown as curve *B* in Fig. 3, corrected at the high frequencies on the basis of the Fletcher and Munson data,[4] has been found to produce very good results in theaters having volumes greater than 300,000 cubic-feet. However, a more nearly flat characteristic at the low frequencies seems to produce the best results in theaters or preview rooms having volumes less than 50,000 cubic-feet.

Curve *C* in Fig. 3 is based upon empirical studies and design practice,[5] and shows ratios of reverberation time in per cent at 128 cycles to the time at 512 cycles, as a function of size. It will be noted that while the greatest departures from the MacNair values are for rooms of 10,000 cubic-feet or less, there is no appreciable departure for theaters of very large volumes. Curve *D* in Fig. 3 is a similar expression of the values at 256 cycles.

A number of successful theaters and preview rooms have been planned in accordance with these data. It seems possible that a reconsideration of desirable times at 512 cycles may also be necessary in the future, since experience indicates that higher reverberation times can be used when more attention is given to the control of sound by design and surface shaping.

While it is possible to plan theaters in such a way that acoustical materials are not necessarily required, it would be very optimistic to expect that such a practice might be adopted universally. Acoustical materials will no doubt generally be needed in modern theaters of large seating capacity. They may also be required in smaller theaters where the architect prefers the use of plain unbroken surfaces to studied acoustical forms. Whatever the case may be, these materials can now be used to much better advantage than they have been in the past.

It has been common practice to cover surfaces almost completely with acoustical materials, or to confine these materials to single surfaces such as the ceiling. Apparently this has been done for two reasons: first, because it seems easier architecturally to cover an entire surface than only selected parts of a surface, and second, be-

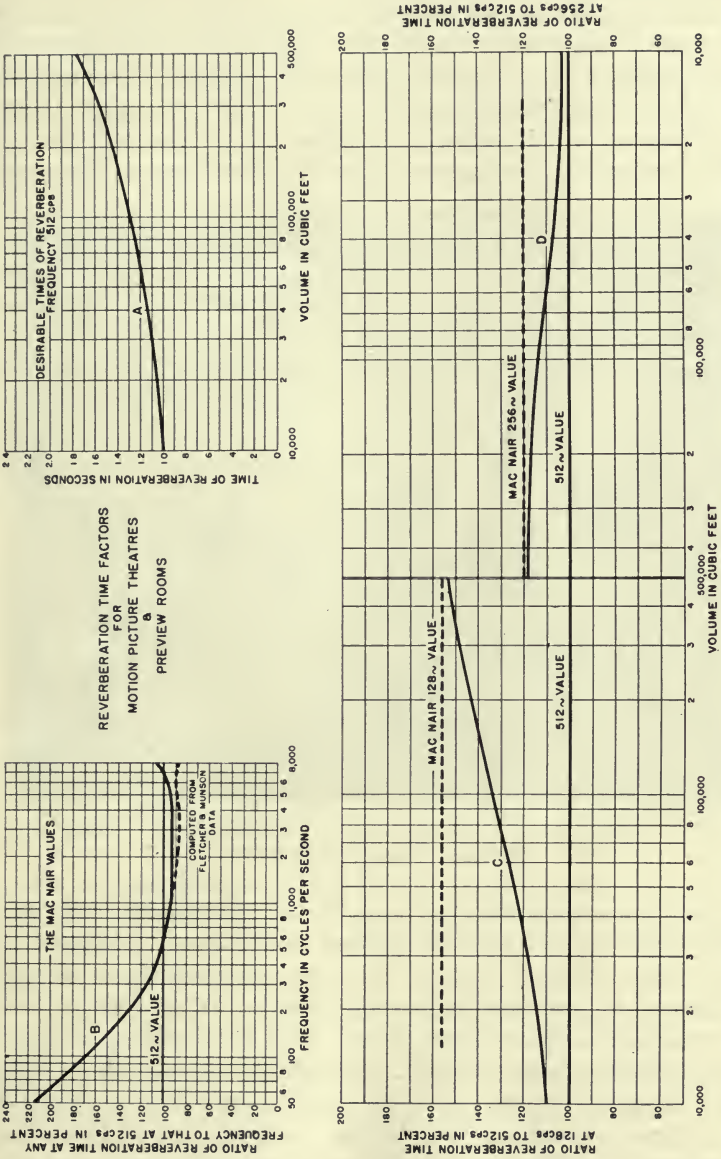

FIG. 3. Reverberation time factors for motion picture theaters and preview rooms.

cause the importance and value of distributing materials have not been fully understood or appreciated.

Actually, absorbing materials prove most effective when they are used in small quantities non-uniformly, instead of being concentrated in large compact masses on single surfaces.[6] This method of acoustical treatment was first tried and the results observed in sound recording studios and scoring stages. With the use of materials non-uniformly distributed, leaving some areas for reflection on all surfaces,

FIG. 4. Typical sound recording studio before installation of decorative coverings over acoustical material.

the quality of sound as picked up by the microphone was exceptionally pleasing and natural, without the effects of "deadness" so characteristic of many rooms of this type. Reverberation measurements made in these spaces showed a practically logarithmic decay for all frequencies, modulated slightly by a large number of low-intensity pattern changes but free of any high-intensity ones. These results checked very well with the types of sound decay measured in other spaces noted for their excellent acoustical properties. It appeared that the background reverberation should be made up of long-path, or what have been termed "around-the-room," reflections, and

that the discrete or short-path reflections of high intensity should be either absorbed quickly or directed away from the microphone area. This conclusion was also supported by subjective reactions as to the most pleasing types of sound decay.

Fig. 4 is a photograph of a typical sound recording studio, taken before any final decorative covering was installed over the acoustical material. Particular attention is directed to the arrangement of acoustical treatment and to the fact that sound reflecting areas, varying in size and arrangement, are retained on all surfaces around the absorbing panels. The absorbing material on the upper wall areas is widely and non-uniformly distributed with respect to opposite sides and ends of the room, in order that the long-path reflections for pleasing background reverberation may be established and maintained. The treatment is more closely spaced on the lower wall areas in order to prevent discrete reflections from reaching the microphone. In this case the non-symmetrical arrangement of acoustical material has been coördinated with angular contours on the walls and ceiling.

Recently this new method of treatment has been used with equally successful results where acoustical materials were required in motion picture theaters. If, in addition, it is combined with irregular shaping of surfaces the quantity of material needed is usually less than that required for theaters of regular form.

Several other significant points in connection with this method of treatment have a definite bearing upon the acoustical characteristics of the motion picture theater. Low-frequency reverberation, or boominess, has been a prime offender in many instances. Measurements show that when materials are distributed non-uniformly their effective absorption is increased at the low frequencies.

This method of treatment also leads to economy in theater construction. It is certainly more economical to use less material and distribute it efficiently than it is to use large amounts and possibly produce "dead" conditions in a theater.

The fact that this arrangement of treatment does not look especially artistic at first glance should not discredit its possible use if intelligently handled from the decorative viewpoint. Although covering materials have been used in the past to disguise the irregular distribution, architects tell us that they see no reason why decorative patterns following such a scheme can not be worked out directly on a surface so as to give a pleasing effect.

Fig. 5 shows a section and interior view of a theater recently completed at the University of Wisconsin. This theater seats 1400 persons and is used both for sound motion pictures and stage productions. The walls consist of a series of convexly curved forms coördinated with a non-symmetrical arrangement of sound-absorbing material. The

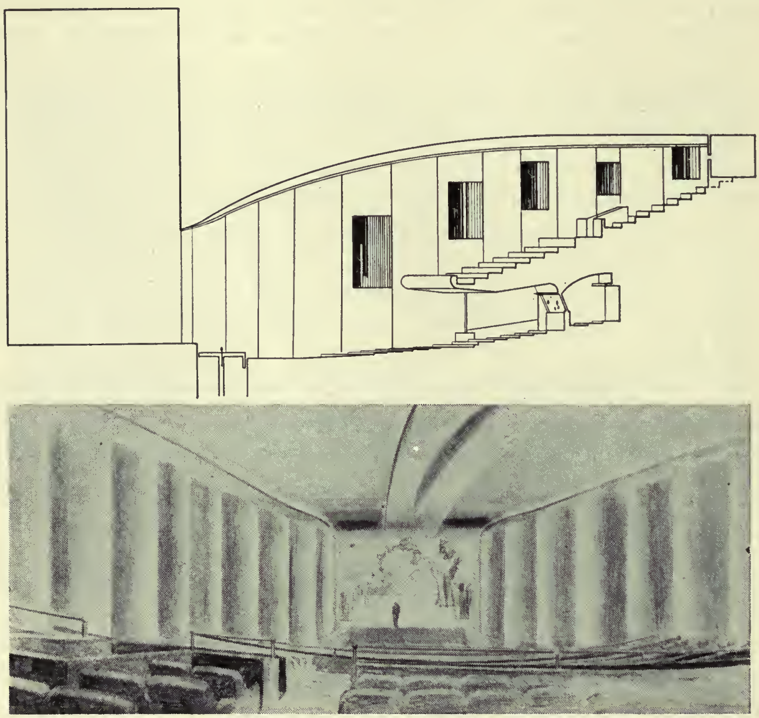

Fig. 5. Wisconsin Union Theater, University of Wisconsin. (*Upper*) Section showing outline form and distribution of acoustical treatment; (*lower*) panorama view of interior.

ceiling follows a gradually decreasing curvature from the stage opening to the rear of the balcony.

The arrangement of acoustical panels along one side wall is shown on the section drawing. These panels are non-symmetrically spaced with respect to the panels on the opposite side. They are covered with a perforated board installed flush with the hard plaster surface, and are painted a matching color.

The balcony rear wall is both acoustically shaped and non-uniformly treated to prevent echoes; the balcony edge is convexly rounded to scatter direct reflections; the balcony soffit is sloped to strengthen the sound level under the balcony; and a sliding glass partition at the rear is tilted so that reflections from this surface will not reach the forward seating area.

It is interesting to note that although this theater has an enclosed volume of almost 300,000 cubic-feet, only 750 sabines of acoustical material are used. In spite of this, the percentage articulation at the extreme rear of the balcony under empty house conditions is 84 per cent.[7]

This represents a theater of large seating capacity, where a small amount of absorbing material was needed to complete the acoustical design. For an example of a theater of more nearly average size, where no acoustical material was used, attention is directed to a theater design described at the Detroit convention in 1938.[8] This theater seats approximately 900 persons and is located in Hamden, Conn. The side walls consist of a series of angular forms running horizontally instead of vertically, the rear wall is convexly curved, and the reverberation time is controlled by limiting the cubic-foot volume. No measurements have been made as yet, but listening tests indicate that sound reflections are being efficiently controlled by the interior surface shaping.

In conclusion, the author wishes again to emphasize the importance of the auditorium as a part of the complete sound transmission system. It either serves to support the impression the director chose to convey through the medium of sound or it tends to destroy that impression. The acoustical design of theaters and the strategic use of absorbing materials, properly coördinated with the acoustical characteristics of the sound-reproducing system, can contribute much to the psychological effect of "carrying the listener into the scene."

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DISCUSSION

MR. KELLOGG: I believe Professor Cook of Princeton University had some ideas about the shaping of surfaces to get the optimum result. Are his ideas being followed and found useful?

MR. POTWIN: Professor Cook did some experimental work on the shaping of ceilings. As a matter of fact, I believe we can go back beyond that, to several auditoriums in Europe where ceilings were shaped to take advantage of beneficial reflection. Professor Cook's original work was done in connection with a proposed new opera house at Philadelphia, in which the ceiling was to be shaped to reflect sound to the audience. He has recently carried the scheme further and has superimposed a series of small concave curves on the major curve in the development of the cross-sectional form. Such a ceiling is used in the Princeton Playhouse.

The ceiling of the Wisconsin University Theater which I have shown differs from the Cook ceiling in that it is perfectly flat in the cross-section, meeting the walls at right angles, and is shaped longitudinally to heighten the acoustical image in only the rear half of the balcony.

MR. KELLOGG: Wasn't it one of Professor Cook's fundamental principles to try to avoid any reflection that was more than about 50 feet, or less, behind the original sound?

MR. POTWIN: Yes, such a relation was worked out for the entire seating area beyond a point approximately 30 feet from the stage. This was done for a single-floor house of the stadium type, where the seating area sloped up rather sharply toward the rear.

MR. KELLOGG: In Fig. 1 you illustrated something that has puzzled me. If you assume that the sound starts from a point about the center of the screen, and you draw a diagram of its paths, assuming that it will be reflected from each surface at the same angle at which it strikes the surface, there does not appear to be any action that would eventually establish a system of waves going straight up and down. How, then, does the flutter between floor and ceiling get started? It has occurred to me that it might be a grating effect. The tone that you reported as being reinforced by this flutter was 400 cps. The spacing of the seats is not very far from $^1/_{400}$ seconds in travelling time. Do you think that the rows of seats might have acted as a diffraction grating?

MR. POTWIN: Not in this case, because there was an open area of approximately 20 feet between the stage and the first row of seats.

MR. RYDER: The same phenomenon has been observed out west. There is a small theater in the San Fernando Valley where it was felt that the seating ar-

rangement had reinforced the frequency band at approximately 400 cycles. The effect was not definitely the flutter-echo effect—that sharp click-back that you get from a flutter-echo, but was a tearing-up or too strong a signal in the 400-cycle range which tended to disturb the dialog intelligibility.

MR. POTWIN: The flutter-echo was equally pronounced in this case without any seats in the room.

MR. LUBCKE: Do you believe that the technic you have outlined, notably skewed walls and small surfaces of absorption material, would be applicable to sound production stages where generally the volume is much greater?

MR. POTWIN: Very definitely. However, in that case coördinating the distribution of acoustical treatment with surface shaping would involve the use of much more absorbing material than is usually needed for the theater in view of the much larger volume of the enclosed space.

MR. RICHARDSON: In the Pix theater at White Plains, N. Y., the ceiling curves down gradually to the walls, which are perfectly plain and flat. An acoustical material was used, and the sound is eminently satisfactory.

MR. POTWIN: We were consultants to Mr. Schlanger, the architect, in the remodelling of the Pix Theater. It is a very long house, and there would have been quite a strong kick-back from the rear wall as a result of the 25-foot increase in length. The rear wall was perfectly flat and could not be changed structurally. The only additional acoustical treatment installed was a 1-inch rock-wool blanket to cover the original acoustical plaster on this surface. The acoustical plaster was retained on the ceiling (the side walls were ordinary plaster) and in order to avoid bad reflections at the front of the house within the new extension, this entire section was shaped for sound control.

MR. RICHARDSON: Are you following the same design at Hamden as you did in the Pix?

MR. POTWIN: The Hamden Theater has horizontal angular forms and the Pix Theater has vertical angular forms, and they differ in dimensions.

AN INVESTIGATION OF THE INFLUENCE OF THE NEGATIVE AND POSITIVE MATERIALS ON GROUND NOISE*

O. SANDVIK AND W. K. GRIMWOOD**

Summary.—*This paper deals with the effect of the negative sound-track upon the ground noise of the print. Data are presented showing the influence of negative density and negative gamma on print ground noise for fine-, medium-, and coarse-grain negative emulsions.*

In the early days of sound recording on film, the noise due to grain structure was almost completely obscured by the noise caused by dirt and abrasion. When, in 1934, the present authors[1] published a paper on ground noise, film handling technic had progressed to a point where it was possible to present data on the noise arising from the granular structure of the photographic image.

Since that time further improvements, not only in film handling but also in maintaining good contact during the printing operation, have made it possible to evaluate with a fair degree of accuracy the extent to which the print noise level is dependent on the negative grain noise.

This present investigation of ground noise was undertaken primarily to determine the degree to which the granularity of the variable-density sound negative affected that portion of the print ground noise which is due to grain structure.

Three commercially available emulsions, which may be roughly classified as fine-, medium-, and coarse-grain emulsions, were chosen for negative materials. Each negative material was exposed so as to give a series of densities, each fifty feet in length, covering a density range of zero to the maximum obtainable with the exposing equipment used. In those cases where the density was not limited by the exposing means, the upper limit of density was chosen as approximately 2.0. Such a set of negatives of different densities was made at

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; Communication No. 763 from the Kodak Research Laboratories, received May 1, 1940.

** Eastman Kodak Co., Rochester, N. Y.

several gammas. The negatives were developed on a continuous processing machine and printed on a non-slip printer with an unfiltered tungsten lamp. Each negative condition of density and gamma was printed to a series of densities covering the range of 0 to 2.0. Two print materials were used, namely: regular cine positive *1301* and the fine-grain master positive material, *1365*. Each print material was developed to the gamma that would give satisfactory picture print contrasts.

Fig. 1 is a block diagram of the measuring equipment used. *R* is the sound reproducer, employing a standard type of optical system.

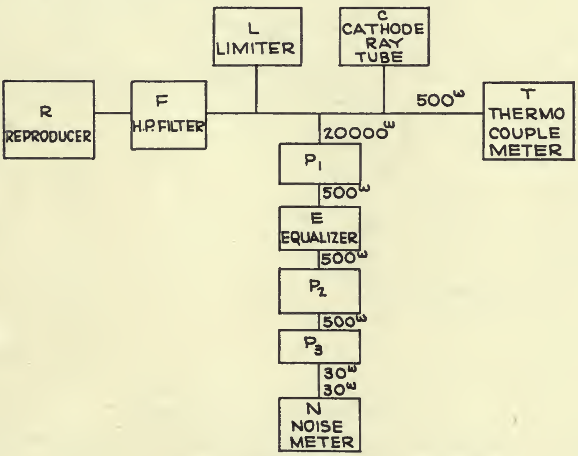

FIG. 1. Ground noise measuring equipment.

The usual coiled-filament lamp is replaced by an 18-ampere ribbon-filament lamp to minimize microphonic difficulties. The noise level of the reproducer is primarily the "shot effect" noise of the photocell and the thermal agitation noise of the photocell coupling resistors. The noise level with the reproducer running is less than $^1/_2$ db higher than with the machine stationary. The minimum ground noise that can be measured is determined by the amplifier noise level which is 75–76 db below the level of a signal produced by a 100 per cent modulation of the exciter lamp output. The amplifier is equalized to compensate for reproducing losses up to 10,000 cps, so that the output of the reproducer for frequencies below 10,000 cps is proportional to the transmission changes of the film.

F is a high-pass filter of 150 cps, which is used to eliminate errors from density variations caused by development effects such as the 96-cycle density variation which occurs near the sprocket holes. Trials made with a 500-cps high-pass filter indicated that the 96-cycle variations were reduced to a negligible value when using the lower cut-off filter. The thermocouple meter, T, of 500 ohms resistance, gives a true power measurement of the ground noise with a flat frequency response between 150 and 10,000 cps. The limiter, L, is designed to protect the thermocouple from high-amplitude surges such as might be caused by splices or deep abrasions on the film. The cathode-ray tube is not used for measuring, but is very valuable in determining

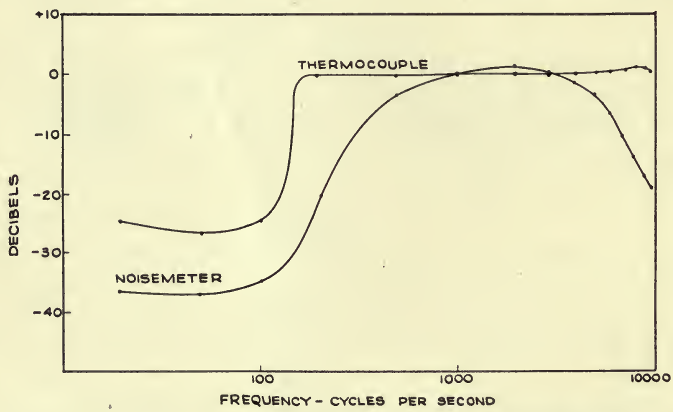

FIG. 2. Frequency response characteristics of ground noise reproducer.

when noise is present from sources other than the granularity of the emulsion.

The thermocouple input is bridged by a 20-db, 20,000- to 500-ohm pad, P_1, which goes to the equalizer, E. This equalizer matches the standard electrical characteristics for theater reproducers as specified by the Academy of Motion Picture Arts and Sciences.[2] From the equalizer the signal goes through a 30-db 500-ohm pad, P_2, a 20-db 500- to 30-ohm matching pad, P_3, to the noisemeter, N. N is a commercial noisemeter whose characteristics conform to the specifications of the American Standards Association and is used with a frequency response approximating that of the ear at a loudness level of 40 db. The noisemeter indication is taken as a rough indication of what the ear would hear as film noise in an auditorium.

Fig. 2 shows the overall response from film transmission to meter indication of the two measuring systems.

RESULTS

A typical ground noise curve is shown in Fig. 3 where the upper curve represents data taken with the thermocouple meter and flat frequency response, and the lower curve represents data taken with

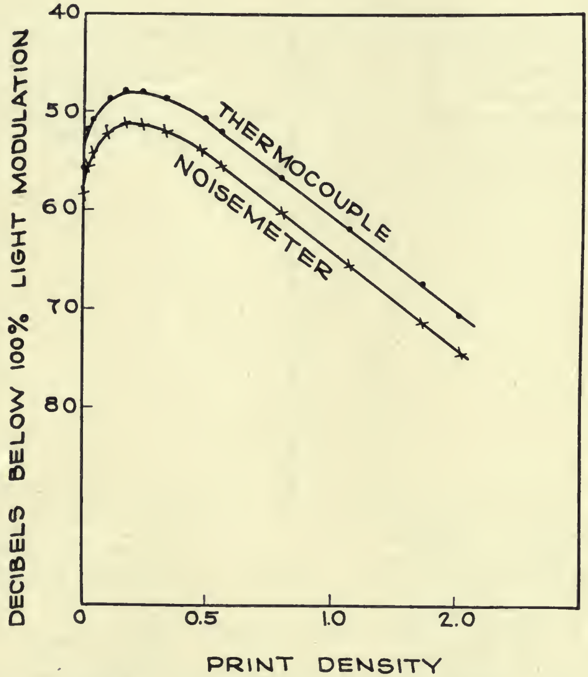

FIG. 3. Print ground noise *vs.* print density.

the noisemeter and a weighted frequency response. At zero print density the noise has a measurable value (though variable from one test film to another) which is due to abrasions, developer sludge, and base imperfections, and does not indicate grain noise since there are no silver grains present. As the density is increased to measurable values, the noise due to the silver grains increases and soon obscures the decreasing base and abrasion noise. The noise due to grains reaches a maximum at a diffuse density of approximately 0.2 above which the noise decreases. Above a density of 0.4 to 0.5 the noise

decreases linearly with the increase of density until the density becomes so high that amplifier noise begins to affect the readings as indicated by the point at which the noise curves begin to bend over and finally become asymptotic to the density axis at a level determined by the amplifier noise; in these measurements, this occurred at a level of −75 decibels.

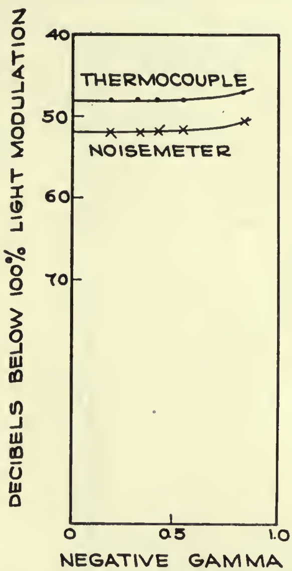

FIG. 4. Print ground noise *vs*. negative gamma.

Negative: *1359*. Density = 0.50. Developer *B*. Print: *1301*. Density = 0.65. Gamma = 2.1. Developer *D-16*.

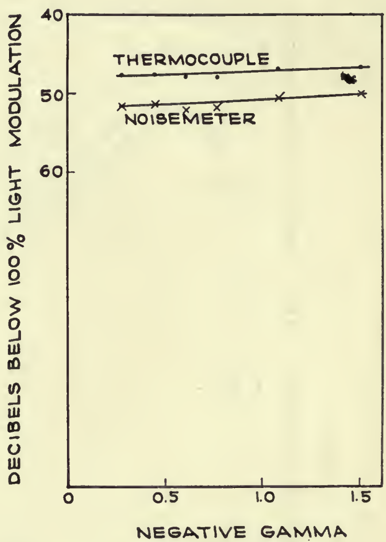

FIG. 5. Print ground noise *vs*. negative gamma.

Negative: *1357*. Density = 0.50. Developer *C*. Print: *1301*. Density = 0.65. Gamma = 2.2. Developer *D-16*.

The original measurements were of print ground noise as a function of print density for a fixed negative gamma and density. A large number of such curves were obtained, each curve corresponding to a different negative condition. By replotting these curves, other families of curves were obtained showing the print noise, at a given print density, as a function of either the negative density or the negative gamma. Fig. 4 is one such curve in which the ground noise of a normal print is plotted against negative gamma for a chosen negative and print density. It will be seen that the print noise is independent

of the negative gamma for values of gamma lying within the range normally used in sound recording. It will be noted further that the print noise is independent of the negative densities for values of negative densities below 1.0 at the normal negative gamma of 0.35.

Fig. 5 presents similar data for negatives developed in a higher potential developer than those of Fig. 4. Here the curves have a

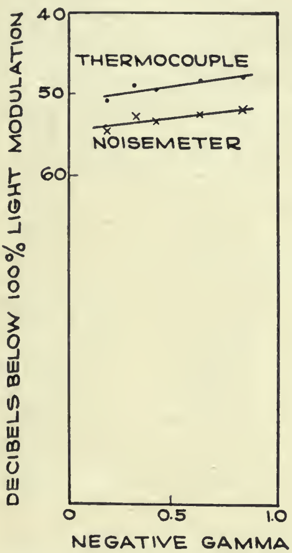

FIG. 6. Print ground noise *vs.* negative gamma.

Negative: *1359.* Density = 0.50. Developer *B.* Print: *1365.* Density = 0.65. Gamma = 2.2. Developer *D-16.*

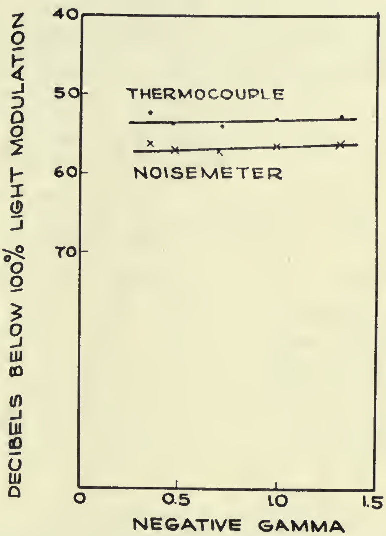

FIG. 7. Print ground noise *vs.* negative gamma.

Negative: *1365.* Density = 0.50. Developer *A.* Print: *1365.* Density = 0.65. Gamma = 2.5. Developer *D-16.*

slight upward slope, indicating that the negative is contributing to the print noise.

The data in Fig. 6 are similar to those in Fig. 4 except that the prints were made on the fine-grain master positive film instead of regular cine positive. It will be noted that, because of the finer-grain positive emulsion, the noise level of the print is no longer independent of the negative sensitometric conditions. These conditions, especially the negative gamma, now have a decided effect on the print noise. For the range of densities and gamma normally used in sound record-

ing, the absolute value of the print noise is appreciably lower for the fine-grain master positive print than for prints made on regular cine positive film. The fact that the negative does contribute to the noise level of a fine-grain print, however, indicates that a finer-grain negative would result in still further improvement in noise level. That such is actually the case is shown by Fig. 7 which gives the noise level of a fine-grain print as a function of the gamma of a fine-grain negative. The print noise is again only slightly dependent on negative conditions and its absolute value is of the order of 5 db less than that for normal sound-recording negatives and cine positive prints. This same fine-grain negative, when printed on regular cine positive stock, gives a print noise level which is almost completely independent of the negative density and gamma and is very nearly of the same

TABLE I

Noise Levels of Negative and Positive Materials

Material	Developer	Density	Gamma	Noise Level (thermocouple)
Fine grain	*A*	0.50	0.35	−60.5
Medium grain	*C*	0.50	0.35	−56.7
Medium grain	*B*	0.50	0.35	−55.4
Coarse grain	*C*	0.50	0.35	−46.3
Cine positive	*D-16*	0.65	2.1	−49.3
Fine grain	*D-16*	0.65	2.4	−54.0

absolute level as a cine positive print of the medium-grain negative. Hence, there is little or no improvement of noise level to be expected from using a fine-grain negative material in combination with a medium-grain size print material.

Further corroboration of the influence of the negative on print noise is found in data for prints from a coarse-grain negative material. Prints from this negative show an increase of approximately 1.5 db for every 0.2 increase in gamma. Using this type of negative material, no improvement in the noise level is found by the use of a fine-grain print material.

Data on the noise levels of negative alone and positive material alone are given in Table I. These data are not given as accurate values of noise level since that may vary somewhat according to the composition and age of the developer, but are intended to indicate approximate values. The data show that the noise level of the fine-grain emulsion used as a variable-density sound-recording negative

material is approximately 4 db less than that of the regular negative emulsion under the corresponding sensitometric conditions. Similarly, the noise level of the fine-grain emulsion used as a positive material is about 5 db less than that of regular cine positive under the corresponding sensitometric conditions. The noise level of the fine-grain emulsion, when exposed and processed to conform to the normal sensitometric conditions of a variable-density negative, is approximately 6 db lower than the noise level of the same emulsion when exposed and processed in accordance with the normal print conditions. This indicates that, for optimum print noise level, when the same material is used for both negative and print, the negative

TABLE II

Comparative Noise Levels of Normal Prints

Material		Developer		Density		Gamma		Noise Level	
Neg.	Print	Neg.	Print	Neg.	Print	Neg.	Print	Thermo-couple	Noise-meter
1365	1365	*A*	*D-16*	0.50	0.65	0.35	2.26	−54.3	−57.6
1365	1301	*A*	*D-16*	0.50	0.65	0.35	2.14	−50.0	−53.2
1357	1365	*A*	*D-16*	0.51	0.65	0.35	2.26	−52.7	−56.0
1357	1365	*C*	*D-16*	0.51	0.65	0.35	2.36	−52.2	−55.8
1357	1301	*A*	*D-16*	0.51	0.65	0.35	2.20	−50.2	−53.9
1357	1301	*C*	*D-16*	0.51	0.65	0.35	2.14	−50.2	−53.7
1232	1365	*C*	*D-16*	0.50	0.65	0.37	2.24	−48.3	−52.7
1232	1301	*C*	*D-16*	0.50	0.65	0.37	2.20	−46.9	−50.3

should be developed to a higher gamma than is normally used, and the print should be developed to a correspondingly lower gamma.

While the data on any one series of prints are believed to be accurate, the validity of comparing different sets of prints is questionable because it was sometimes necessary to replace the positive developer. Furthermore, some of the data indicate that the noise level may change appreciably with small changes in the developer throughout its normal life.

To obtain a direct comparison of the noise levels from the types of emulsion previously measured, a second set of negatives was made, the negative conditions in this case being fixed at a density of 0.50 and a gamma of 0.35. Each negative was printed to a series of print densities, care being taken to handle all prints alike. The results obtained on this second set are shown in Table II. It will be observed that these data check closely with the data in Table III which are

taken from curves derived from the complete sets of negatives and prints.

The noise level of a photographic sound recording is but one of many factors affecting the general sound quality. When the noise level is reduced by the use of fine-grain emulsions, there are simultaneous improvements in the resolution and wave-form of low-modulation signals, resulting in greater improvement in quality than would be expected on the basis of noise measurements alone.

One method of showing graphically the result of a change in sound recording negative and print emulsions is to measure the relation

TABLE III

Comparative Noise Levels of Normal Prints

Emulsion	Developer	Emulsion	Gamma	Thermocouple	Noisemeter
1365	*A*	1365	2.5	−53.7	−57.3
1365	*A*	1301	2.2	−49.5	−53.0
1359	*B*	1365	2.5	−49.8	−53.5
1359	*B*	1301	2.1	−48.0	−52.0
1357	*C*	1365	2.5	−51.0	−54.9
1357	*C*	1301	2.2	−47.7	−51.6
1232	*C*	1365	2.4	−47.7	−51.8
1232	*C*	1301	2.0	−47.8	−51.2

Negative gamma = 0.35
Negative density = 0.50
Print density = 0.65
Print developer, *D-16*

between print output level and recorder input level for several frequencies.

Fig. 8 is a graph of such a measurement. The output level corresponding to 100 per cent modulation of the recording light-beam has been adjusted to zero for all frequencies. One set of curves represents a *1301* print of a *1357* negative, and the other represents a fine-grain print of a fine-grain negative. The range of outputs over which the output level departs from linearity with the input level by less than 2 db is from 6 to 9 db greater for the fine-grain negative and print than for the *1357-1301* combination. A more detailed discussion of the significance of this type of measurement will be given in a later paper.

In all the data taken there is a constant difference of about 4 db between thermocouple readings and the noisemeter measurements.

In view of the widely different frequency responses used for these two measurements, this indicates that the frequency distribution of grain noise is the same for the three types of emulsions and over the range of sensitometric conditions covered by the measurements.

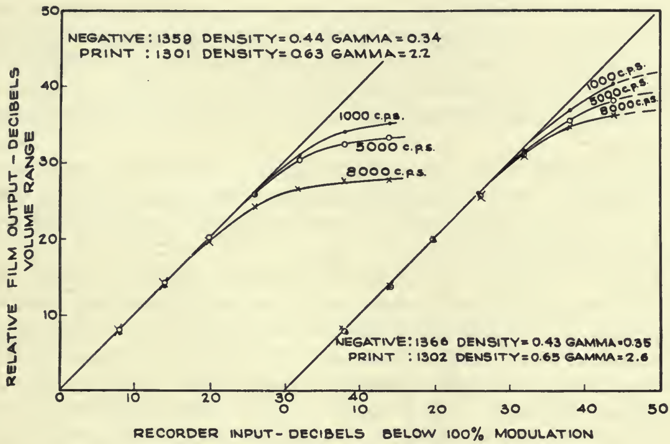

FIG. 8. Volume range of variable-density prints.

More information on the frequency distribution of film noise will be presented in a later paper, in which certain aspects of ground noise relative to the variable-area type of sound-track will be discussed.

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[1] SANDVIK, O., HALL, V. C., AND GRIMWOOD, W. K.: "Further Investigation of Ground Noise in Photographic Sound Records," *J. Soc. Mot. Pict. Eng.*, **XXII** (Feb., 1934), p. 83.

[2] "Standard Electrical Characteristic for Two Way Reproducing Systems in Theaters, *Acad. Mot. Pict. Arts & Sci.*, Techn. Bull., (March 31, 1937).

[3] GOETZ, A., GOULD, W. O., AND DEMBER, A.: "The Objective Measurement of the Graininess of Photographic Emulsions," *J. Soc. Mot. Pict. Eng.*, **XXXIV** (March, 1940), p. 279.

DISCUSSION

MR. ROBERTS: Have you made any tests on the influence of the type of light-source? Is there any difference between a highly collimated light-source, with which you probably made these tests, and a very diffused light-source?

MR. GRIMWOOD: We have not made any tests on the effect of the degree of specularity of the light-source. Tests made some years ago with a projection printer showed a marked dependence of the frequency response on the diffusion of

the light-source, indicating poorer definition with a different source. This would lead us to expect that the portion of the print noise due to the negative would be less for a diffuse light-source than for a highly specular source.

MR. McNABB: Has any study been made of the subjective effect of noise, as would be occasioned by the response of the human ear? Was a weighting network inserted in the equipment to approximate the characteristics of the human ear?

MR. GRIMWOOD: We used the weighting network for a loudness level of 40 db with the standard noise-meter. That probably represents fairly closely what the ear would hear for a continuous noise; but in the case of clicks from abrasion I do not believe a noise-meter indication would mean much in terms of what the ear actually hears.

MR. McNABB: I do not know whether I am right or not in my assumption that all noise frequencies are equally objectionable so long as they are equally persistent. In broadcasting work, for instance, weighting networks are not used in noise-measuring equipment.

MR. RYDER: In Hollywood we have made quite extensive tests on audience reaction to noise. We have introduced the type of background noise that we normally think of as film noise, and listened to or watched for audience reaction. Watching audience reaction is a thing we do all the time in connection with preview work, so that we become reasonably conscious of the audience reaction. We find that audiences do not quiet down if there is a noise in a theater, especially if the noise is of a type that is irritating. A higher level noise of 60 cycles, or even 120 cycles, does not seem to irritate the audience nearly as much as the higher-frequency noises, such as the film noise. We were quite pleased by the contrasts in audience reaction observed during tests on the picture *Geronimo*, where we obtained attention and audience quietness from fine-grain prints as contrasted with normal release prints.

MR. McNABB: The main reason I bring up the question is that in the broadcasting field, noise-measuring technic does not permit a higher level at 60 or 120 cycles than it does of higher-frequency noises similar to film noise. Have you made any check on the subjective characteristics of noise?

MR. GRIMWOOD: No. We have not attempted to evaluate the psychological effects of the noise.

MR. McNABB: I notice that you said you used a weighted curve.

MR. GRIMWOOD: For one set of measurements, yes.

MR. McNABB: A weighted curve is not used, I believe, in broadcast work, because, as I understood it at that time, the persistence of a noise, regardless of its frequency, is what makes it undesirable. That does not seem to agree very well with the facts.

MR. RYDER: I think their problem is a little different from ours; for instance, the loading that we would normally apply when considering sound volumes as used in the theaters, is not a correct loading for home listening on the radio. The problem is different, and maybe there is good reason for it.

MR. CRABTREE: What is the relation between the noise reduction you get by changing films and the noise increase you get from (*a*) the accumulation of scratches during the normal projection life of a film, and (*b*) the accumulation of silver sludge on the film in case you do not filter the developer.

MR. GRIMWOOD: We have no data on that point. It is hard to evaluate the effect of an increase due to scratches and noises of that nature, which are much more objectionable than the steady noise from grains. This work was confined entirely to the grain noise. We were interested in the limits to which it can go—and the minimum value to be expected.

As far as developer sludge is concerned, we did find indications of the noise varying somewhat during the life of a developer—variations of the order of one db or possibly two db, which may have been due to that cause.

MR. BOYER: Have you made any correlation between the noise and the graininess of the film as contrasted with grain size? Have you used the method on negatives of fairly large grain size so that the graininess between films could be measured?

MR. GRIMWOOD: We have not tried to correlate visual graininess data with noise measurement. Dr. Goetz and others, working at the California Institute of Technology, have done much work on graininess measurements. He reports[3] a definite correlation between objective and subjective measurements for materials covering a wide range of grain sizes. His published work does not, so far as I know, state whether the correlation holds for prints of a negative.

MR. KELLOGG: Have you tested this with ultraviolet light?

MR. GRIMWOOD: We have found no appreciable difference in ground noise of low-gamma negatives exposed with ultraviolet radiation as compared with tungsten exposures. These tests have not, however, been sufficiently comprehensive to state definitely that there is no difference. No tests have been made at high gammas or in printing with ultraviolet light.

MR. RYDER: Our experience indicates that the improvement available from ultraviolet light is much less on fine-grain film than on standard film. The whole field is too new for any of us to make any positive statements in this regard.

FILTERING FACTORS OF THE MAGNETIC DRIVE*

R. O. DREW AND E. W. KELLOGG**

Summary.—*A laboratory model of a magnetic-drive film-phonograph was modified so that speed fluctuations of large and measurable magnitude and of frequencies ranging from $^1/_2$ to 7 cycles could be introduced either into the sprocket rotation or the magnet rotation. The resulting speed variations at the drum were determined by means of a "wowmeter." The large ratios of flutter reduction indicated by these measurements show in part why the magnetic drive gives unsurpassed film motion.*

THE MAGNETIC DRIVE SYSTEM CONSIDERED AS A MECHANICAL FILTER

The magnetic drive as used in RCA recorders and in film phonographs for re-recording has been the subject of several technical papers,[1, 2, 3] in which general statements are made in regard to its effectiveness as a filter, but up to the present no measurements have been reported which show in definite terms how much speed fluctuation occurs at the drum as the result of fluctuations of given magnitude in the driving system. Several months ago, the authors undertook a series of measurements with this end in view, and although the data leave something to be desired in the way of precision, it is felt that their significance is not appreciably impaired thereby and that their interest is sufficient to warrant reporting.

Mechanical filtering has been widely employed in machines for recording sound on film or reproducing the same, to provide smooth motion of the film at the translation point. In most such mechanical filters the film is carried on a rotating drum, on the shaft of which is a flywheel. In order that the drum may run at uniform speed, attempt is made to minimize all the forces which might act to accelerate or retard it. To this end, whatever means are used to transmit to the drum shaft the continuous torque needed to maintain its rotation are of a very yielding character, as, for example, soft springs or flexible loops of film. When this is done, if there are periodic speed fluctuations in the driving system, these flexible connections take up the

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received May 23, 1940.

** RCA Manufacturing Co., Camden, N. J.

resulting phase-shifts between the driving system and the uniformly running drum. They can not absolutely protect the drum from the effect of the fluctuations, but can make that effect extremely small. The "filtering factor" is the ratio of speed variations at the drum to those at the source of the disturbance.

The "rotary stabilizer," which in principle is closely related to the magnetic drive, has been well analyzed by E. D. Cook.[4] In both systems damping of the drum shaft is provided by a viscous coupling to a second member which is rotating at the same or nearly the same speed. The viscous coupling is an oil film in one case and is electromagnetic in the other. In order that the viscous coupling may provide the desired damping, the second rotating member must not participate appreciably in the speed variations of the drum. In the case of the rotary stabilizer, the second member is a flywheel whose inertia prevents it from changing speed appreciably, while in the case of the magnetic drive the second rotating element, against which the damping forces react (namely the magnet), is geared to the driving motor. This geared connection has a double effect of providing a relatively enormous effective mass, so that the magnet speed will be almost completely independent of any forces which may act upon it through the viscous coupling (a condition for optimum damping) but it may introduce certain small disturbances into the magnet speed, due to such imperfections as exist in the gearing. In the original paper describing the magnetic drive system,[1] a calculation is given on the basis of which it is shown that magnet speed fluctuations of considerable magnitude result in such small speed changes at the drum as to be of no particular consequence.

It would be a simple matter to make determinations of stiffness of film loops and of moments of inertia of the rotating parts, and on this basis to calculate the amount of speed fluctuation at the drum which would result from given fluctuations at the controlling sprockets. Some such calculations are given herein. The writers felt that an experimental attack would be of more general interest and perhaps more convincing to those who are not mathematically inclined.

Residual Irregularities.—Since in the best of machines there is some residual speed irregularity or flutter, it is practically necessary in measuring the filtering ratio that the irregularities deliberately introduced and measured shall be of exaggerated magnitude so that the residual imperfections in the film motion will not mask the speed variations which are deliberately introduced, or make it difficult to

estimate their magnitude. In spite of resort to this expedient, the drum speed fluctuations which were of the same frequency as, and attributable to, the artificially introduced disturbances, were in many cases too small to estimate with any assurance.

Effects of Disturbances Originating at the Drum Shaft.—Disturbances at the drum may originate in irregularities of motion at the sprockets, or in the magnet rotation, or be due to unbalance or variations in friction at the drum shaft itself. The last-named effects, namely, disturbances originating at the drum shaft, are not peculiar to the magnetic drive. In fact, they are necessarily present in every film-propelling device. The magnitude of such disturbing forces is largely a question of mechanical perfection and of lubrication. The speed fluctuations which given forces will produce depend upon the mechanical impedance at the drum shaft. The fact that the magnets take the brunt of the acceleration load means that a flywheel of generous proportions may be employed. This is the first requisite for providing the desired high mechanical impedance to resist forces tending to cause speed changes. There is, however, in every type of filter (excepting those which do not provide synchronous operation) some form of elastic connection between the drum and the remainder of the system comprising the sprockets, gearing, and motor. The existence of such an elastic connection means that resonance can occur at some frequency. For any disturbance which repeats itself at this resonance frequency, the mechanical impedance of the drum shaft is no longer a question of flywheel inertia, but primarily one of resistance or damping. The advantages of strong damping, which can readily be obtained with the magnetic drive, will be discussed later in connection with Fig. 7.

We have not considered that there was occasion for including any considerable series of experiments to show the effect of drum-bearing disturbances. It may be assumed that in high-class machines, such as sound recorders, unbalance will be reduced to negligible magnitude and the bearings will be the best obtainable. The following calculations will show that reasonable manufacturing care will bring the unbalance far within the tolerance range.

Assuming a flywheel weighing 11 pounds, having a radius of gyration of 2.8 inches and a 2-inch drum diameter, we find that 1 inch-ounce of unbalance will cause the speed to change by 0.085 per cent above and below average, or an rms fluctuation of 0.06 per cent. Although it is desirable to avoid a "wow" of even this small magni-

tude, it should be borne in mind that 1 inch-ounce would be an inexcusably large unbalance (corresponding for example to mounting the flywheel 0.005 inch eccentric), and that according to present standards, recording machines are considered in excellent condition if when tested on a flutter bridge which includes all frequencies between about one cycle per second and 100 cycles, the rms flutter is 0.2 per cent or less.

EXPERIMENTAL METHOD AND APPARATUS

The principal work of which this paper is a report, consisted in introducing disturbances of measured amplitude and frequency, first in the sprocket rotation and then in the magnet rotation, and in measuring the corresponding speed fluctuations at the drum by means

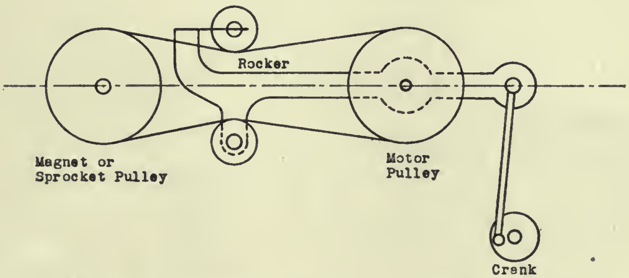


FIG. 1. Method of introducing speed changes.

of a "wowmeter" which makes an oscillographic record of the instantaneous speed covering a period of six seconds. The "wowmeter" has been described by Morgan and Kellogg.[5] A 1000-cycle record is used, and the "wowmeter" makes a record of the variations in frequency. It has a substantially linear scale from 985 to 1015 cycles. The position of the light-spot on the oscillograph film can be placed wherever desired so that the mean position of the oscillograph trace on its film is no indication of the average frequency. This permits a number of oscillograms to be shown on the same film, and their value is not impaired by the fact that they do not show the absolute speed. It is, however, important to know that the frequency is at all times within the 3 per cent range. Means are provided for checking the average frequency before each oscillogram is made.

The method of introducing disturbances consisted in driving both the sprocket and magnets by means of belts, and passing each belt

around a pair of idler pulleys which could be periodically shifted so as to produce a phase change between the driving and driven pulleys. Fig. 1 shows schematically the belt and rocker arrangement. The machine used for the tests was one of the original models of the RCA magnetic drive recorder, an experimental machine which afforded the desired accessibility to the driving system. The drum is cut short and the machine was used as a reproducer, a photocell being located within the hollow drum. A 1000-cycle record, itself of low flutter content, was spliced into a loop and run through the machine.

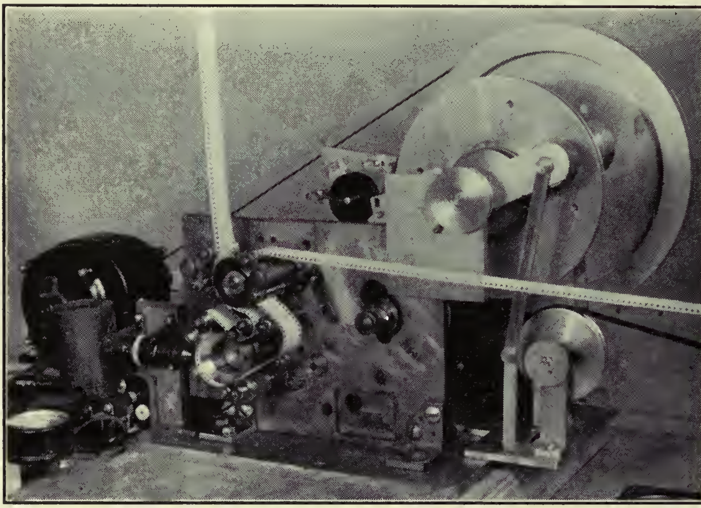


FIG. 2. Film-phonograph equipped for introducing disturbances.

The film path is not exactly the same as that of present RCA recorders, but the net film loop stiffness is not materially different. Therefore, the writers feel that the results are fairly representative. The movable idler rollers for introducing "wows" were mounted on a rocker driven through a connecting rod and crank. The crank was driven by a separate motor, the speed of which could be varied. The throw of the crank could also be changed to any of five positions. One of the belt idlers was rigidly mounted on the rocker, and the other was sprung so that it maintained a substantially constant pressure against the belt, to keep it tight.

Fig. 2 is a front view of the machine, showing the main driving motor, the constant-speed jack-shaft and the marks on the sprocket

pulley, magnets and flywheel, for making stroboscopic observations. Fig. 3 is a rear view showing the film path and part of the rocker driving system. The rocker is here shown as locked in fixed position for making a reference or zero disturbance oscillogram. The holes for the five crank-pin positions are seen in the crank disk at the lower right.

The inclusion of numerous belts and pulleys in the driving system is, of course, not ideal for flutter-free operation and may be responsible

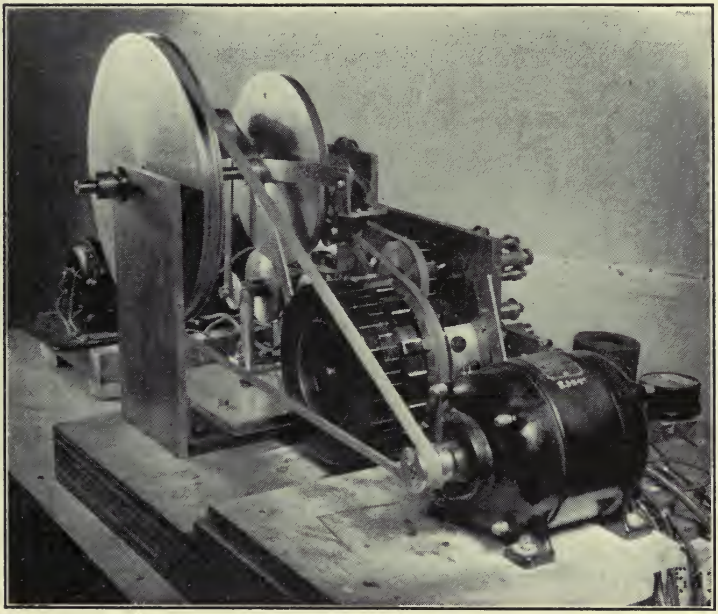


FIG. 3. Rear view of film-phonograph.

for part of the residual flutter which appears in the oscillograms even when the rocker is stationary, and which is superimposed on the "wows" which result from the working of the rocker.

In making a test, the film-phonograph was started and the frequency of the output checked; then the rocker was started and an oscillogram made, record being kept of the frequency of the rocker motion and of the crank position. The actual phase-shift at the sprocket pulley or at the periphery of the magnet was measured for each crank length, first statically and then checked by stroboscope when the machine was running. The two measurements checked

very satisfactorily, showing that there was no appreciable belt slippage under any condition. Without such a check, it was hardly safe to assume that the magnets, whose inertia is high, would execute as large movements at full speed as they would when the rocker was moved slowly from one position to another. A rubberized endless woven belt supplied by the Russell Manufacturing Company was employed to drive the magnets.

Fig. 4 shows a time-exposure of the stroboscopically illuminated marks on the magnet. On account of the small number of flashes per cycle of oscillation, a visual estimate of the amplitude of swing was difficult, but the time-exposure covering a number of cycles was very satisfactory, it being found possible to hold the drift to practically zero during the exposure. Table I shows the amplitudes of swing for each of the five crank positions.

TABLE I

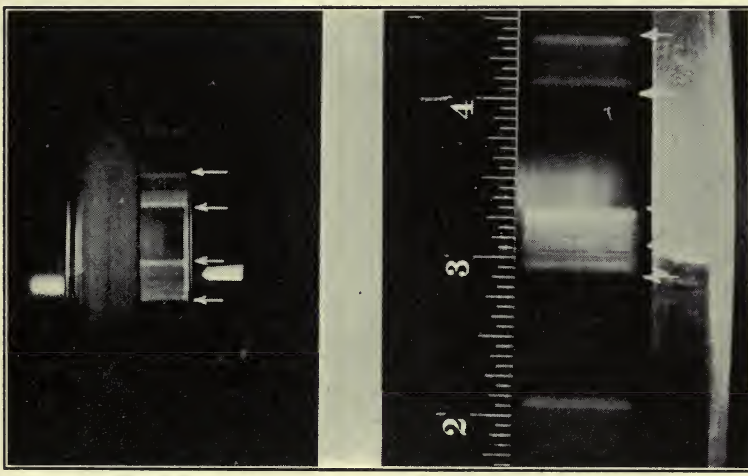
Speed Changes in Magnet and Sprocket Caused by Motion of Rocker

Magnet Drive					
Crank position	1	2	3	4	5
Observed double amplitude at periphery = $2a$	0.16	0.295	0.50	0.690	0.770
Swing in revolutions $2a/D$ (Diameter = D = 7″, Speed = 214 rpm = 3.56 rps)	0.0073	0.0134	0.0227	0.0314	0.035
Sprocket Drive					
Observed double amplitude at periphery = $2a$ (3″ pulley)	0.080	0.15	0.230	0.315	0.430
Corresponding movement at sprocket radius	0.0255	0.0478	0.0732	0.100	0.139

Effects of Loop Size.—As is well known to those who are at all familiar with the magnetic drive, the machines are designed so that the magnets supply slightly more forward torque to the drum shaft than is necessary to overcome friction, and thus subject the loop of film above the drum to a slight tension, which may range from almost zero to two or three ounces, depending on magnet current adjustment. The film as it leaves the drum is in a long free loop and exerts negligible force. In the tests wherein oscillations were put into the sprocket motion, the magnet current was adjusted to give three representative upper loops which we have designated as tight, normal, and slack. Fig. 5 shows the approximate shapes of these loops. In the

tests with fluctuating magnet speed, two different average magnet speeds were used in order that the effect of changing magnetic coupling might be tested without at the same time altering the loop tension. Thus high magnet current and reduced slip gave the same loop as higher slip and a weaker magnet.

Fig. 6 shows the characteristic of a film loop similar to the upper loop in the machine on which our tests were made. It will be noted that stiffness increases rapidly with increased tension. This means that the degree of filtering of sprocket disturbances and the natural



Sprocket Pulley Magnet

FIG. 4. Time exposure of stroboscope mark.

frequency of the filter system (as determined by flywheel inertia and film stiffness) are radically changed by film tension. Thus at one ounce average tension, the loop stiffness, for small changes, is seven ounces per inch; at two ounces it is twenty-three ounces per inch; and at four ounces it is 130 ounces per inch. These would give, with the flywheel and drum dimensions of the machine we used, natural frequencies of about 0.23, 0.40, and 1.0 cycle per second. Fig. 7 shows the characteristics of a filter of the fundamental type of the magnetic drive. The filtering is calculated on the basis of the analogous electrical circuit. Voltage corresponds to an alternating disturbing force, and current to the velocity of an alternating motion. In the case of the mechanical system both the motion and the force are con-

tinuous, but pulsating in character when cyclic disturbances are present. The pulsating force or velocity is considered to be the resultant of a continuous or constant plus an alternating force or velocity, and in the analysis of filter characteristics, only the alternating component is considered.

Since no attempt was made when the measurements were taken to specify with exactness what we called "normal," "slack," and "tight" loops, we can offer only an approximate check between the calculated and the measured "wows" at the drum. From the observed ratios of filtering between sprocket and drum, (where the observed amplitude at the drum was large enough to be measured with any assurance) and from the natural period of oscillation, it appears

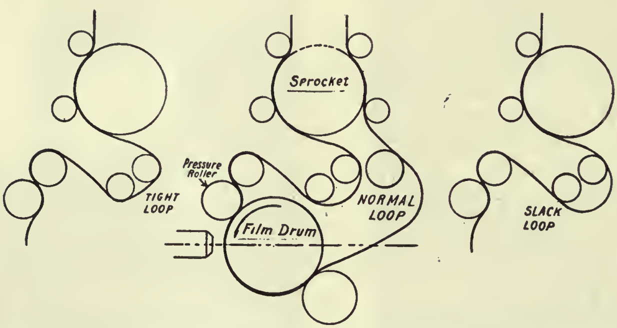


FIG. 5. Sketches of loops: light, normal, and slack.

that "normal loop" corresponded to a loop stiffness of the order of eight ounces per inch, with about one ounce average tension. The natural frequency was about one cycle in four seconds. In the *PR-23* recorder, which is the principal example of commercial magnetic drive, the slowest running gear is the one on the sprocket shaft, which turns three revolutions per second. Cyclic or rhythmic disturbances of lower frequency are practically non-existent, and it is only to cyclic disturbances that the curves of Fig. 7 are directly applicable. Since the lowest frequency of disturbance in practical applications is of the order of twelve times the natural frequency of the drum and flywheel, the filtering ratio for these cyclic disturbances in film motion at the sprocket would be very high and may be taken as substantially equal to the ratio of flywheel inertia-reactance to film-loop stiffness-reactance, or 144 to 1. Damping is scarcely a factor in the filtering of disturbances so far above the natural fre-

quency. The magnets help the filtering of these disturbances, not so much by the damping they introduce as by the fact that they make it possible by supplying driving torque, to work with loops under very low tension. Damping is of great importance in connection with transient disturbances, due, for example, to starting or to passing of splices. With inadequate damping, such a disturbance may start a train of oscillations which persists for a long time. The magnets also assist greatly in bringing the flywheel up to speed.

Although there may be no definitely cyclic disturbances below sprocket rotation frequency, there are small random disturbances

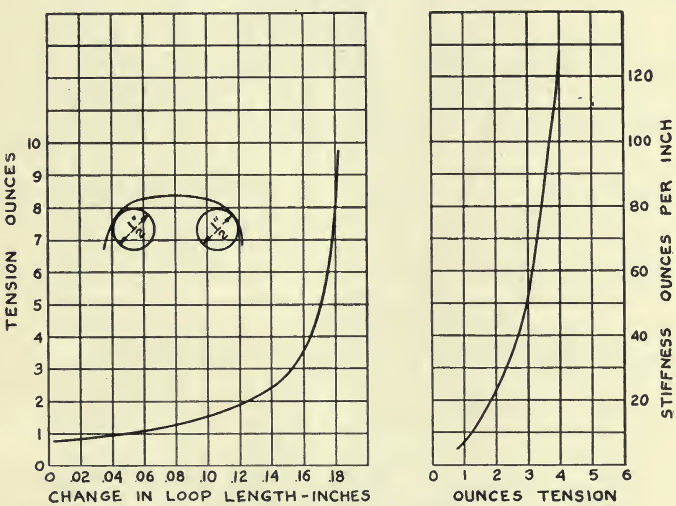


FIG. 6. Film loop characteristics.

whose origin is hard to trace but which make plenty of trouble in an inadequately damped system. Some possible causes are variations in the stiffness of the film from point to point, which cause variations in the force transmitted through a loop, friction which does not exactly repeat its pattern from one revolution to the next, and jerks from the film supply or take-up systems. It is these random disturbances which have been the downfall of practically all undamped systems.

Referring to Fig. 7, it will be seen that with the damping corresponding to curve *I*, at the highest point on the curve ($f/f_0 = 0.7$) the speed changes at the drum are 15 per cent greater than at the sprocket, but if the damping is only one-fifth as much as that which gave curve

I, the speed changes would be five times greater at the drum than at the sprocket, as shown in curve *II*. Forces which act in a random manner can impart energy to oscillating systems at any frequency to which these systems are sensitive. The energy imparted within a narrow range of frequency is small, and since the forces or

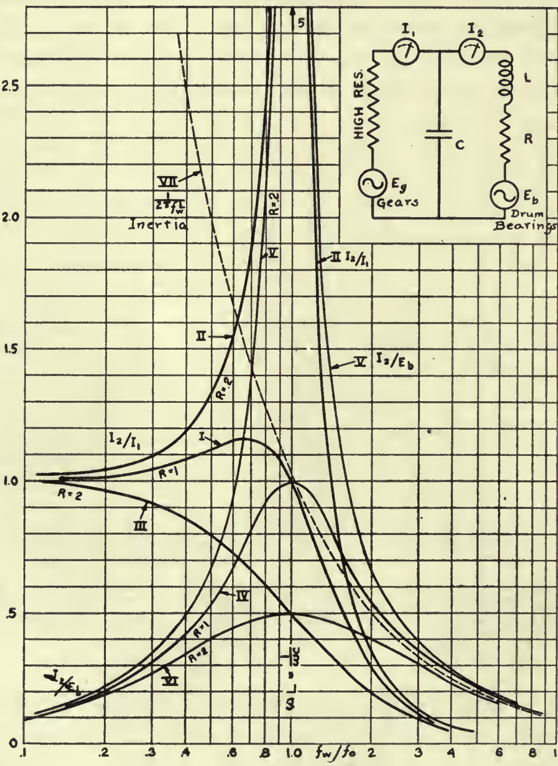


FIG. 7. Filter characteristics.

disturbances themselves are small in a well built machine, the harmful effect on drum motion is negligible unless the resonant properties of the filter cause a considerable magnification of the disturbances. For this reason, curve *I* represents a performance which experience has shown to be very satisfactory, while curve *II* would result in chronic trouble from "wows," which will come and go in an erratic manner.

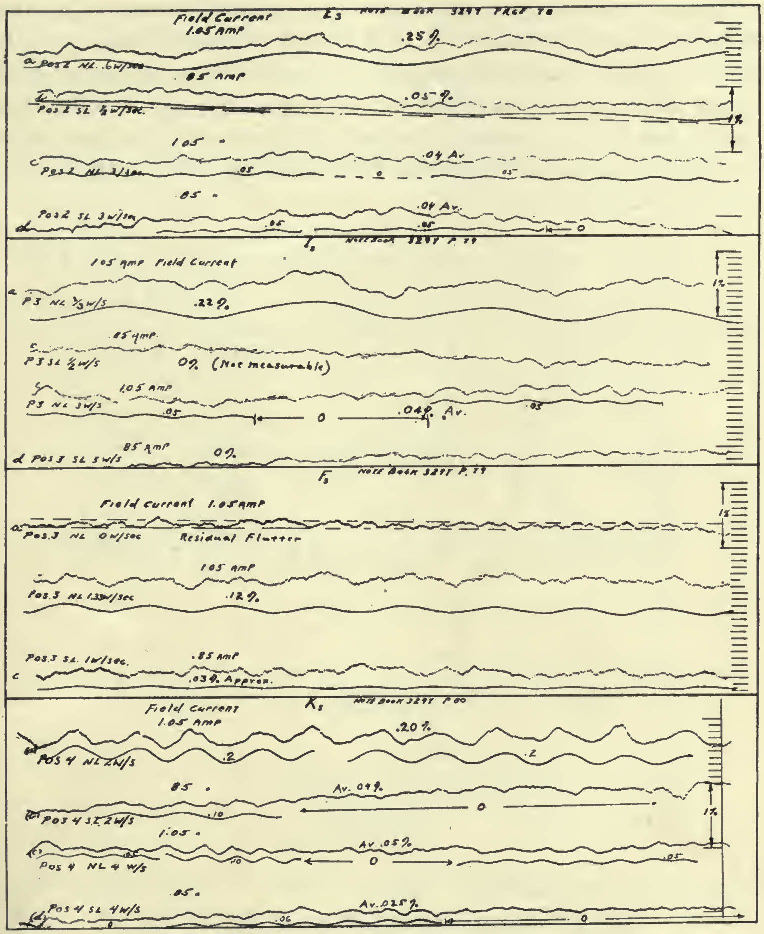


FIG. 8. Effects of driving sprocket at irregular speed.

MEASURED DRUM SPEED FLUCTUATIONS WITH DISTURBANCES AT SPROCKET

Fig. 8 shows a number of oscillograms, selected as representative of those taken. One of the traces was made with no sprocket "wows" introduced, and thus represents the imperfections in the film plus the residual disturbances in the machine used for the tests when acting as a reproducer or film-phonograph. The oscillograms look ragged, but in judging this, the sensitivity of the "wowmeter" must be considered. The total variation, minimum to maximum in a period of six seconds, is about 0.2 per cent, and if slow changes (of the order of 0.1 per cent

in this case) taking place over a period of several seconds are eliminated, as is very commonly done in flutter measurements, it will be recognized that this represents a good standard of performance in recording machines. It is sufficient, however, to make it difficult to estimate the flutter produced by the operation of the rocker, when that flutter is small, and the smaller values are thus open to considerable question.

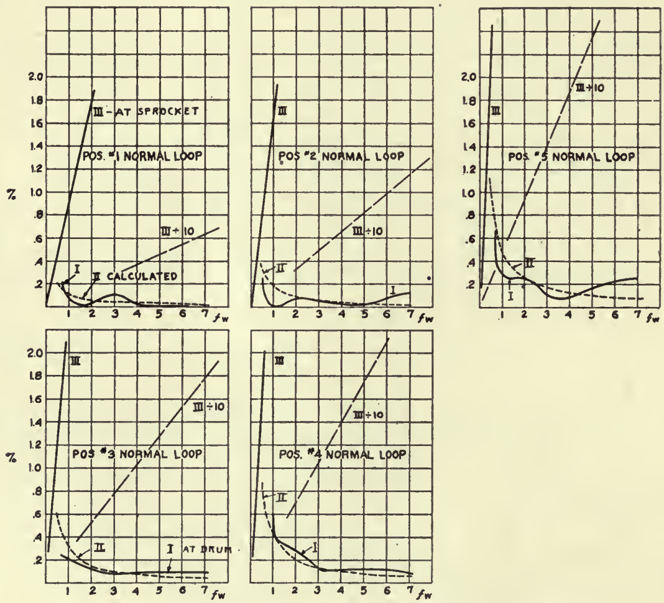


FIG. 9. Calculated and observed amplitudes (normal loop).

Curves *I;* measured values of speed fluctuation.
Curves *II;* calculated.
Curves *III;* speed fluctuations at sprocket.

A purely objective method of measuring that portion of the total flutter which is of the same frequency as the rocker motion would have been desirable but would have required equipment which was not available. We therefore simply made visual estimates. Directly under a number of the oscillograms are sinusoidal curves which in our estimation represent approximately the amplitude of the component of the same frequency in the recorder flutter. From these curves, the reader may check whether the figures reported fairly rep-

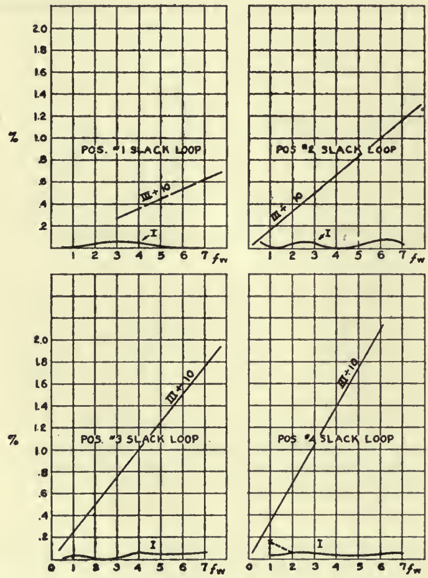
resent the flutter resulting from the disturbances introduced by the rocker. A scale is shown at the end of the oscillogram. The estimated double amplitude of speed fluctuation, in per cent of average film speed, is marked on the curve. Although the method of determining the magnitude of the flutter is crude, it can certainly be said that the true value does not materially exceed the figure given. This gives a basis for stating that the filtering ratio is at least as large as reported.

Fig. 9 is a series of plots on which the measured values of flutter amplitude are shown by the solid curves marked *I*. Calculated curves, marked *II*, are also drawn showing the theoretical shape of

FIG. 10. Comparison of motion at sprocket (a) and at drum (b). (a, zero field current 2 w/sec., pos. 1; b, normal size loop, 2 w/sec., pos. 1.)

the flutter amplitude curve, based on the assumption of a loop stiffness of eight ounces per inch. In making all the oscillograms, the galvanometer of the "wowmeter" was shunted by a condenser, so that it would not record the rapid flutter due to vibration and other factors having nothing to do with the relatively low-frequency "wows" introduced by the rocker which we were attempting to measure. The "wowmeter" was calibrated with the condenser in place, and corrections applied for the differences in response at the several rocker frequencies used. The straight lines through the origins in Fig. 9 (marked *III* in each case) show the magnitude of the per cent speed variations at the sprocket as calculated from the rocker frequency and amplitude of phase-shift. These curves run off the edge of the diagrams and are continued at one-tenth scale in the lines marked

III ÷ 10. Fig. 10 is a pair of oscillograms made to give a direct indication of the relative speed changes at the sprocket and at the drum. Curve *b* is made in the usual way (but with the rocker in action). Curve *a* is made with the drum locked and the film sliding over it, thus making it serve as a gate. The pressure-roller was lifted, but a light pressure-finger applied to hold the film against the drum, and to cause the film to be pulled tight between the reproducing point on the drum and the sprocket. Under these conditions the speed fluctuations at the scanning point are substantially the same as at the sprocket.



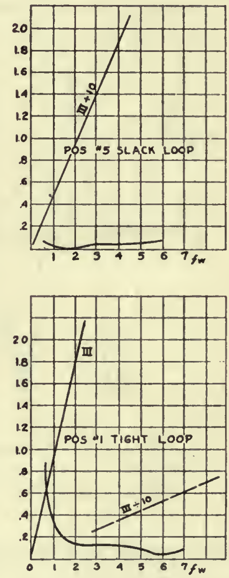


FIG. 11. Speed fluctuations (slack loop). FIG. 12. (tight loop).

Fig. 11 is a set of curves similar to those of Fig. 9, but based on oscillograms made with a slack loop. In practically all cases the flutter of rocker frequency was so small that its measurement was very uncertain. The actual stiffness of the slack loop is difficult to estimate, but is evidently so low that practically no disturbance is transmitted through the loop, except perhaps at the lowest rocker frequencies tried.

Fig. 12 shows a similar plot based on oscillograms made with a tight loop. Only the smallest crank throw was used with a tight loop,

since otherwise the phase-shifts at the sprocket are sufficient to take up practically all the excess film in the loop and subject the film at the drum to a series of violent jerks, unlike anything that could happen in service.

Fig. 13 shows the filtering ratios as derived from the data of Fig. 9. Owing to the large range of values to be covered, a logarithmic scale has been used.

DRUM-SPEED CHANGES DUE TO IRREGULARITIES IN MAGNET-SPEED

It is a simple matter to calculate the drum-speed fluctuations produced by magnet-speed variations, provided the coefficient of coupling and the moment of inertia are known. If there should be any magnet-speed fluctuations of frequency near the natural frequency of the system, then the effect of the film loop must be taken into account. This is indicated by the difference between curves *IV* and *VII* of Fig. 7. The effects of magnet-speed fluctuations may be calculated in the same manner as unbalance or friction variations. The deviations in magnet-speed above and below normal, multiplied by the coefficient of coupling (7.5 inch-ounces per rev. per sec. slip, in the case of our test machine, with 1.05 field amperes, which gave "normal loop") give the accelerating and retarding torques which act on the flywheel. The speed changes at the drum are found by dividing the alternating torque by the mechanical impedance (which in most cases is simply the inertia reactance of the flywheel and drum, or $2\pi f_w I$, where f_w is the frequency of the disturbance and I the moment of inertia of flywheel and drum. Well above resonance a very simple relationship holds; namely, that the drum-

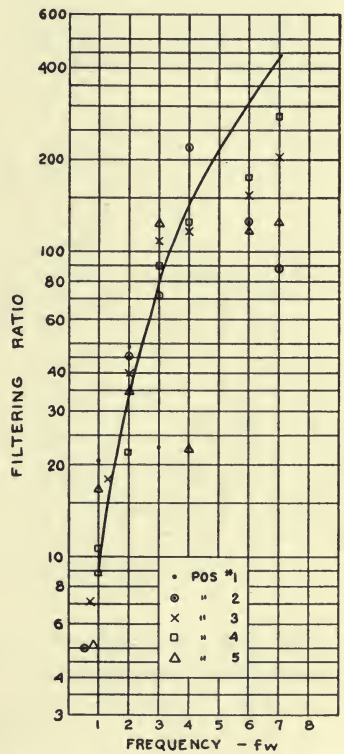


FIG. 13. Filtering ratios for sprocket disturbances.

speed changes bear a fixed relation to the amplitude of the magnet phase-shifts, independently of the frequency of the disturbance. Thus, for example, if an eccentric gear in the magnet-driving system causes the magnets to be advanced and retarded by 0.001 revolution (0.360 degree) with each revolution of the gear, the magnet speed changes will be $2\pi f_w \times (0.001)$ revolutions per second, the torque will

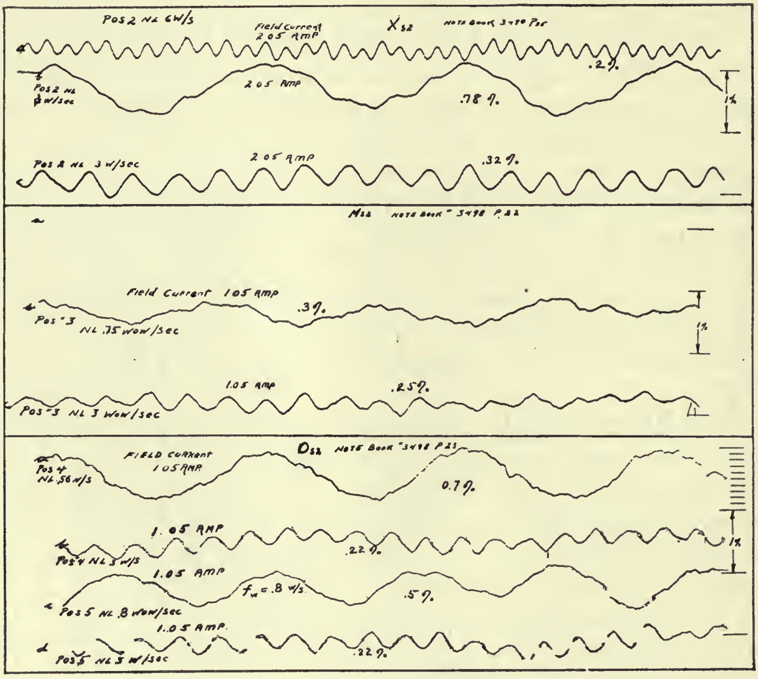


FIG. 14. Effect of driving magnet at irregular speed.

be K times this, where K is the coefficient of coupling, and the drum-speed changes will be

$$\frac{K2\pi f_w(0.001)}{2\pi f_w I} = \frac{0.001K}{I}$$

In our case K equaled 7.5 at 1.05 amperes, and the moment of inertia I for the 11-pound flywheel with 2.8-inch radius of gyration is

$$\frac{Wr^2}{g} = \frac{16 \times 11(2.8)^2}{12 \times 32.2} = 3.57 \text{ oz.-in.}^2$$

TABLE II

Effect of Shifting Magnet; Normal Loop, $I = 1.05$

Crank position	1	2	3	4	5
Double amplitude of excursion at 3.5″ radius (inches)	0.16	0.295	0.5	0.690	0.770
Double amplitude in revolutions	0.0073	0.0134	0.0227	0.0314	0.035
Magnet-speed change, min. to max. per cent at $f_w = 1$	1.28	2.36	4.0	5.50	6.2

Crank Pos. No. 1 $a = 0.0073$			
f_w	M	D	M/D
0.5	0.64	0.130	5
1	1.28	0.143	9
2	2.56	0.181	14
3	3.85	0.117	33
4	5.12	0.143	36
6	7.70	0.119	65
7	8.96	0.132	68
D (calculated)		0.085	

Pos. No. 2 $a = 0.0134$			
f_w	M	D	M/D
0.5	1.18	0.196	6
1	2.37	0.215	11
2	4.74	0.145	32
3	7.11	0.28	25
4	9.48	0.285	33
6	14.22	0.237	60
7	16.59	0.265	62.5
		0.156	

Pos. No. 3 $a = 0.0227$			
f_w	M	D	M/D
0.7	2.8	0.34	8
0.9	3.6	0.28	13
2	8.0	0.27	30
3	12.0	0.35	34
4	16.0	0.285	56
6	24.0	0.316	76
		0.265	

Pos. No. 4 $a = 0.0314$			
f_w	M	D	M/D
0.6	3.3	0.73	4.5
9	4.95	0.39	12.7
2	11.0	0.36	30
3.3	18.2	0.45	40
4	22	0.43	51
		0.365	

Pos. No. 5 $a = 0.035$			
f_w	M	D	M/D
0.8	5.0	0.52	9.6
1.14	7.1	0.44	16
2	12.4	0.36	34
3	18.6	0.47	40
4	25	0.34	74
5.5	34	0.37	92
		0.405	

M = per cent speed fluctuation of magnet (double amplitude).
D = per cent speed fluctuation of drum (double amplitude).
Calculated values of D are based on measurements which indicated 7.5 inch-ounces torque for one rps slip, with 1.05 field amperes.

The drum-speed fluctuations resulting from the magnet-shift assumed would be $(0.001 \times 7.5)/3.57 = 0.0021$ radians per second, which with a two-inch drum would cause a film-speed change of 0.0021 inch per second, or: $0.21/18 = 0.0116$ per cent speed change.

Fig. 14 shows several oscillograms made with the magnets moved forward and backward by the rocker. The measured wows are shown in Table II. The symbol f_w stands for the frequency of the rocker movement, M is the per cent change in magnet-speed, and D is the per cent change in drum-speed. All quantities are given in terms of double amplitude. The magnet current was 1.05 amperes. The ratio of M to D gives an idea of the filtering between the magnet and the drum.

In a series of tests in which the magnets were shifted forward and backward by means of the rocker, we found that the measured "wow" at the drum was practically independent of film-loop tightness except as the tighter loop was obtained by slightly larger magnet current and therefore stronger coupling. At one-half cycle per second there was an increase in amplitude with the tight loop, due to the fact that with the tight loop the resonance of the system was not far removed from the excitation frequency.

IRREGULARITIES IN SLIP-RING CONTACT RESISTANCE

Two brushes on each slip-ring are provided in RCA machines employing magnetic drive, but it has sometimes happened that the surface of a slip-ring became impaired and the magnet current meter jumped with every revolution of the magnets. There were no complaints of the resulting recordings, but naturally "jitters" of the meter needle were transmitted to the nerves of the operator. Fortunately, the film did not know about the meter needle.

In order to measure the effect of a periodic drop in magnet current, we arranged a contact which was opened by a cam during about 30 degrees of magnet rotation. Opening the contact inserted a series resistance and caused the current to drop momentarily. A 14-volt battery was used and the main adjustment rheostat set to give about one ampere through the magnet winding, the loop being maintained by further small adjustments. With the machine running, the meter needle fluctuated violently. Owing to the inductance in the winding, we could not assume that the current dropped to the value determined by resistance alone; therefore checks were made with a cathode-ray tube. Several different values of resistance were inserted by

the opening of the contacts. Fig. 15 shows a series of oscillograms taken with successively greater fluctuations. The inserted resistance and the minimum current, as estimated from the cathode-ray tube trace, is indicated on each oscillogram of Fig. 15. About 21 revolutions of the magnet are represented in the length of the oscillogram. It will be observed that only with the largest values of resistance does any pronounced disturbance appear at magnet-rotation frequency, and this disturbance is still scarcely more than 0.1 per cent. The reason that the interruption in magnet current has so little effect is that at no time is the magnet exerting much force on the flywheel (normally, the magnet torque is of the order of 1.5 inch-ounces) and fluctuations in this small force can not have any large effect, especially in view of the fact that the cycle is repeated three times per second

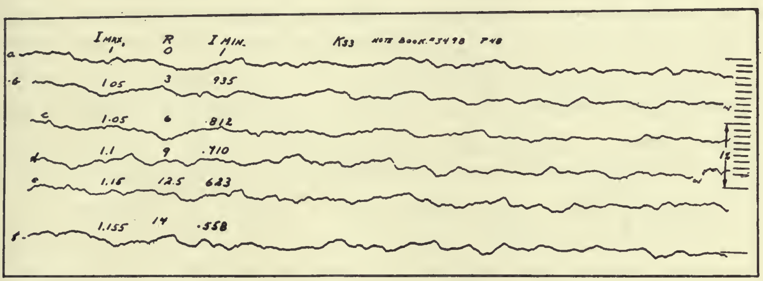


FIG. 15. Effect of interrupting magnet current.

and a force must act for an appreciable time to produce much change in speed.

Obviously we do not advocate permitting slip-rings to remain in bad condition, but we would point out that small kicks of the meter needle need not be cause for alarm.

EFFECT OF TRANSIENT DISTURBANCES

One of the best ways of testing a mechanical filter is to touch the flywheel and watch the film loops. If damping is poor, the oscillation will persist for a number of cycles. The most important single reason for supplying the magnet drive on our machines is that it provides the indispensable damping. The damping varies somewhat from one machine to another, for the reason that if bearing friction is slightly higher in one machine than in another, a higher magnet current is required to give the desired loop. In general, in machines now in

the field, the damping is less than critical. In other words, if the flywheel is disturbed, it will swing back and forth once or twice before the disturbance disappears. Fig. 16 shows several oscillograms in which a sudden retardation was applied to the flywheel. In some cases the oscillograph film was slowed down to twelve seconds per revolution in order to make a complete record of the recovery. The dying out of the transient oscillation is clearly shown. These oscillo-

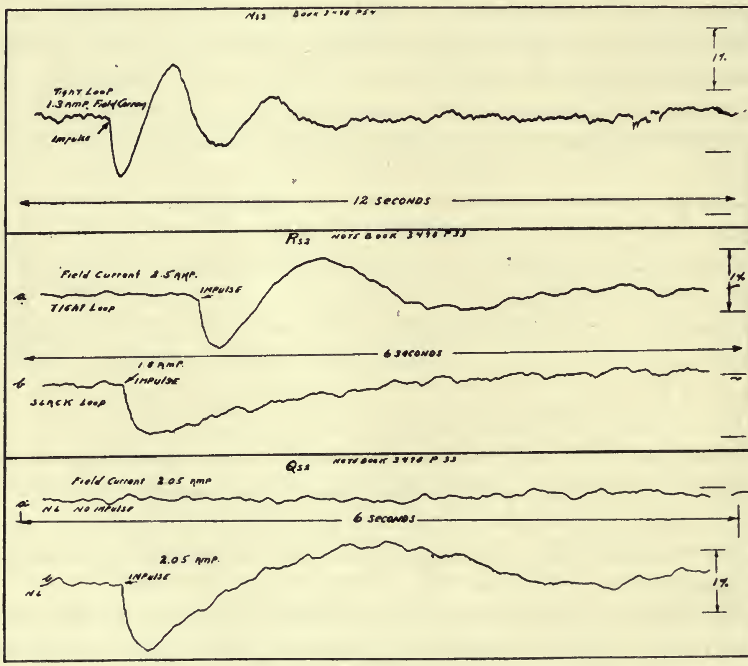


FIG. 16. Effects of touching flywheel.

grams would afford an excellent means of checking the natural frequency, except for the fact that the disturbance introduced was so large as to bring in the effect of non-linearity in the film-loop stiffness. Non-linearity causes the oscillation to be other than sinusoidal, and the period depends on the amplitude, somewhat as a ball, undergoing a series of bounces, keeps changing the period.

In interpreting such an oscillogram of an oscillation, it must be borne in mind that the position of the oscillograph trace above or below the axis is an indication of velocity and not of displacement.

Thus, the flywheel is forced by the applied disturbance to drop back in phase, and there is a period during which the speed is below normal; but in order for the flywheel to come back to normal position, the speed must for a short time be above normal. In a critically damped system, the oscillating member, if displaced in one direction, comes back to normal without swinging beyond the normal position. The direction of motion, however, does reverse. For this reason an oscillogram showing velocities of movement, even if the system is critically damped, will show deflections below and above the axis, the total negative and positive areas becoming equal when the original phase position is reached. This point is brought up to emphasize the fact that slightly different impressions may be given by watching the film-loops in the machine from those gained by looking at the oscillogram. The difference, however, is not especially significant unless it comes to a question of judging whether the system is critically damped or not.

From an examination of a number of oscillograms of transients such as shown in Fig. 16, it appears that the total time required for recovery after a disturbance may be shortened by working with a moderately tight loop. This, however, is not recommended, as the rapid oscillation is likely to make more aural impression, and the ideal way to shorten the duration of a transient is to increase the damping, as this causes the loop to crawl back to normal length with the minimum possible amount of off-speed operation.

CHANGES IN MOTOR VOLTAGE

The effect of a sudden change in the voltage supplied to the driving motor, due, for example, to the starting of some large motor on the system, is a matter about which the user of a recording machine will naturally be concerned, especially where a special power-supply for recorders is not provided. We arranged to produce a sudden drop of about 22 per cent in the voltage supplied to our driving motor. We could observe no effect in the oscillograms. We then observed the motor with a stroboscope, and the effect of the change in voltage was scarcely visible. Obviously, then, we could expect no effect at the film. The induction synchronous motors normally used to drive RCA recorders are heavily damped and very stiff. The stiffness with which a synchronous motor is locked to the supply decreases with the applied voltage, but the greater the inherent stiffness of the motor and the lighter the load, the less is the motor phase-shift. Since little

power is required to drive a recorder, it is not surprising that we could scarcely see any effect on the motor. It is conceivable, however, that for certain purposes, a motor might be employed which would execute a considerable jump in phase when the supply voltage changes. Assume as an extreme case, for example, a phase-shift of ten electrical degrees. The resultant shift at the sprocket would be 10/360 or $^1/_{36}$ of the distance that the film travels in $^1/_{60}$ second; or $^1/_{56}$ of 0.3 inch, or 0.0083 inch. In view of the negligible effect at the drum of much larger disturbances at the sprocket, the inevitable conclusion is that large changes in supplied voltage will produce an imperceptible effect on the film motion.

CONCLUSIONS

The magnetic drive provides very effective filtering for disturbances arising at the sprocket.

The fact that the magnets help to bring the flywheel up to speed and supply all the power required to overcome bearing friction, permits the use of a flywheel of generous size, thereby reducing the sensitivity to imperfections in bearing friction and balance.

The symmetry of construction of the multipole magnet, the large air-gap, and the heavy copper flange permit reasonable manufacturing tolerances without danger of non-uniformity in the magnet drag at various relative positions of magnet and flywheel. This means that there is practically no danger of disturbances occurring at slip frequency.

Irregularities in magnet-speed due to gearing are a conceivable source of disturbance in the drum-speed, but the measured attenuation between the disturbance at the magnet and at the drum is very large, and reasonable manufacturing tolerances make the danger of flutter from this source negligible.

Damping of transients is of great practical importance, even though a machine with low damping may show creditable speed constancy, once steady-state conditions have been reached. The magnetic drive provides a satisfactory degree of damping.

It is the writers' belief that the residual flutters which appear in practically all measurements do not signify any actual changes in the rate of drum rotation, but are rather matters of film shrinkage, contact between film and drum, and vibration. The minimizing of such sources of imperfect film motion depends upon refinements in construction rather than principles of design, and are not characteristic

of any particular type of driving or filtering system. The residual disturbances indicated in our tests are within limits which are found to be highly satisfactory in practice, but they are enough to make it difficult to measure very small effects. The writers are of the opinion that in future designs it will be desirable to use stronger magnetic coupling and correspondingly reduced slip. This increases the possibility of transmitting imperfections in the magnet motion to the drum and therefore may call for closer tolerances in the construction of the magnet driving system than are necessary if the coupling is loose; but it will still be easily possible to make disturbances from this source negligible, while giving the system the benefits of quick starting, quick recovery from transients, and still further reducing the sensitivity to random disturbances which tend to produce oscillatory effects.

In some filter systems damping reduces filtering. For example, if the damping is applied to the flexible element of the filter (analogously to putting the resistance in series with the condenser in Fig. 4) it reduces the ease with which the disturbances are by-passed. Damping the motion of the flywheel as is done in the magnetic drive is analogous to putting the resistance in series with the inductance, thereby increasing the impedance of this branch of the circuit and hence improving the filtering. Correspondingly, flywheel damping increases the mechanical impedance associated with the drum, and does not interfere with the free movements of the film loops as would a damping device which acted on the film loops. Strong damping, as is well shown by comparing curves *III* and *VI* of Fig. 7 with the corresponding curves *I* and *IV* or *II* and *V* for lower damping, makes film-loop adjustment less critical, in that with sufficient damping it is no longer so important to keep the natural frequency very low in comparison with the frequency of possible disturbing forces. If critical damping or more is provided, there is substantial filtering even at $f/f_w = 1$ (instead of an exaggerated disturbance such as takes place if the damping is low). Flywheel damping instead of simply resisting *changes* in speed, resists all departures from normal speed, always pulling back when the speed is too high and exerting a forward pull whenever the speed is below normal.

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DISCUSSION

MR. ALBERSHEIM: The diagram that you showed seems not quite complete. You implied by your remarks that one can have disturbance from the sprocket shaft, as well as the magnets. There are really two sides to the system. You should show another input with another source of disturbance, and another mass and compliance. The total curve includes two resonant systems with one resistance combining the two. Is that not a closer approximation to the actual conditions?

MR. KELLOGG: The diagram shown in Fig. 7 represents a simple system comprising a mass, an elastic element, a resistance, and two sources of disturbance; or, more specifically, a drum and flywheel, connected through a loop of film to a sprocket, damping of the flywheel (by the magnet), and two sources of disturbance, one at the sprocket represented by E_s and one acting at the drum E_b. The latter may be considered as representing not only bearing friction, but also such torque pulsations as result from irregularities in magnet speed. The deviations of magnet speed above and below the average, multiplied by the coefficient of coupling, give the magnitudes of the torque variations tending to disturb the drum motion. This is explained in the paper. We have not omitted anything essential, although, as Mr. Albersheim suggests, a complete electrical analogue for the magnetic drive would include something to represent the magnet driving system (motor and gearing) and the magnet inertia, with a current representing magnet motion. Such a circuit was illustrated in a paper on "A Review of the Quest for Constant Speed" in the April, 1937, JOURNAL.

With regard to the question of what filtering properties the magnet driving system has, we have, of course, considerable inertia in the magnets, but comparatively little compliance in the gearing. I think it safe to say that such disturbance as occurs at gear-tooth frequency will be practically confined to some vibration, the actual changes in rotational speed being extremely small. (Purely vibrational magnet motion does not react on drum speed.) On the other hand, the lower-frequency speed changes due to eccentric gears will scarcely be filtered out at all from the magnet motion. Even inexcusably bad gearing, however, would cause only a small fraction of the magnet wow demonstrated at the Convention, and the effect of this, in turn, on the drum speed was inaudible. Hence we are justified in saying that with good gearing in the magnet drive the disturbance at the drum will be negligibly small.

MR. ALBERSHEIM: The greatest difficulty in this type of drive seems to be the approximate synchronization of the magnet and film drum. You evidently want to drive the magnet a little faster than the synchronous speed, perhaps by 1 per cent or less. What happens if the shrinkage of the film varies? Do you have means for changing the speed of the magnets?

MR. KELLOGG: In the magnetic drive machines of present design the magnets run about 15 per cent faster than the drum. If, owing to shrinkage, the drum should run 1 per cent slower than normal, this would increase the slip, and therefore the magnetically supplied torque, by one part in fifteen. Of course in recorders the shrinkage variation is scarcely one-fourth of one per cent. We also use the magnetic drive in film phonographs and here the shrinkage variation might be as much as 1 per cent. Ordinarily, the magnet current is adjusted to give about the desired loop, with the particular film which is intended to be used, but if various films are spliced together, and no readjustment is made, the changes in loop tension resulting from the small differences in drum speed are far within

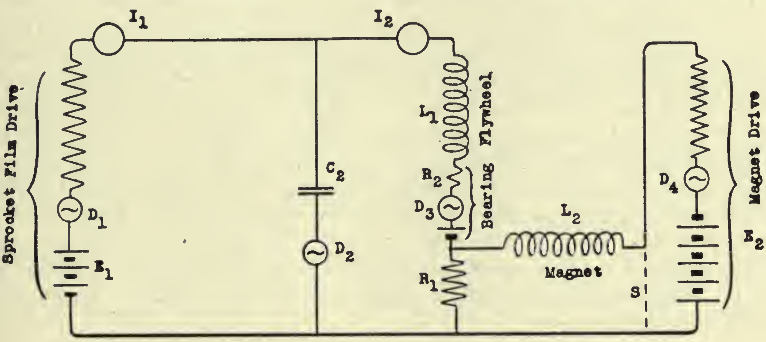

FIG. 17. Electrical analogue of magnetic drive.

Analogies:
I_1, film movement at sprocket.
I_2, film movement at drum.
L_2, mass of magnet.
C_2, flexibility of film loop.
E_1, steady pull of film.
E_2, power supply to magnet.
D_1, disturbances in sprocket drive.
D_2, variations in film stiffness, splices, kinks, *etc.*
D_3, irregularities in drum shaft bearing friction.
D_4, irregularities in magnet drive gears.
R_1, coupling between magnet and flange.
R_2, bearing oil viscosity.
L_3, mass of roller and arm.
S, connection substituted for magnet drive, to make diagram applicable to rotary stabilizer.

the tolerances of loop tension, which can take a range from 50 per cent to 200 per cent of normal without measurably impairing performance.

MR. SEELEY: I wonder if Mr. Kellogg will discuss the advantages of the magnetic damping as compared with viscous or oil damping?

MR. KELLOGG: The magnetism does not spill and does not have to be wiped up with a cloth.

I suppose you would like a little more technical answer than that. There is no fundamental difference except the convenience of regulation. The qualities of the two types of damping are identical; provided, of course, that the viscous damping system does not involve any actual contact. If the damping is purely through a film of oil, then it has identical properties with the magnetic damping.

MR. MAURER: Is it not a fact that the magnetic damping can readily be adjusted to the exact value required, whereas oil damping is subject to variations in temperature?

MR. KELLOGG: Quite true. We could, of course, make an oil-damped device that is adjustable, and the choice would then be pretty much a question of such considerations as weight, cost, maintenance, *etc.*

MR. KELLOGG:* Since the question of a more complete diagram of the analogous electric circuit has been brought up, it seems appropriate to reproduce the illustration which was printed in the April, 1937, JOURNAL. Such compliance or resistance as is brought in by the magnet drive gearing would be represented by a very small capacity, in series with a resistance, connected across at the point marked S (Fig. 17). The nature of such filtering of the magnet motion as this produces has been already discussed.

The batteries E_1 and E_2 and the one just below D_3 represent the continuous driving and frictional forces, but these do not enter into the filtering calculations.

If, as a result of the disturbance D_4, an alternating current I_m flows through the inductance L_2 which corresponds to the magnet mass, the resulting current at I_2 (which represents drum motion irregularities) may be shown to be equal to I_mR_1 divided by the impedance of the circuit comprising R_1, R_2, L_1, and C_2. In this it is assumed that a negligible part of the current would flow around through the I_1 branch, it being part of the assumption that the resistance in that branch is extremely high, or, in other words, that it would take very large forces to appreciably alter the rate of sprocket rotation. The representation in our paper of the effect of magnet speed fluctuation is based on assuming a disturbing voltage equal to I_mR_1, and simply jumps over the derivation of this relation, which seemed unnecessary.

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* Communicated.

CURRENT PRACTICES IN BLOOPING SOUND-FILM*

WM. H. OFFENHAUSER, JR.

Summary.—*A review of dimensional standards fails to indicate any attempt in the past to standardize sound-track bloops. While it is true that there is relatively little difficulty due to bloops at the present time, this condition appears to be due to the fact that each producing organization has more or less independently arrived at some rule-of-thumb solution to its particular problem rather than a result of any directed effort on the part of the industry as a whole.*

The criteria are almost entirely empirical; the common tests are (1) peak volume indicator and (2) listening. This has resulted in a wide variety of bloops in use; a reduction in the number of sizes and types seems desirable in the interest of simplification. For single-track negative bloop punches this is especially important.

The lengths of the bloop punches vary from 0.330 to 0.965 inch. A length of 0.500 inch may be considered to represent "average" practice. There is almost complete agreement on the following characteristics of bloop punches; (1) The punch should be sharp. (2) In the case of the triangle or trapezium types, there should be rounded corners at the base of the triangle.

There is no similar agreement in the use of bloops for sound positives; in the case of release prints, this matter is not especially pressing since release negatives are usually re-recorded and have few, if any, splices.

Our films of today have a much faster tempo than the films of 1928 and 1929; we can characterize this change in a statistical way by saying that our films today have a much larger number of far shorter scenes. This change in tempo has had a number of effects upon the practices in the production of films that do not appear in evidence in the theaters in which the films are shown. One of the practices so affected is blooping.

What is a bloop? Our November, 1931, glossary, while not directly defining a bloop, did define a blooping patch as ". . .a black section approximately triangular in shape introduced over a splice on a positive sound-track to prevent noise that the splice would otherwise cause during reproduction. The patch effects a gradual diminution of the light transmitted through the sound-track followed by gradual restoration to the original value. The patch may be applied with

* Presented at the 1940 Spring Meeting at Atlantic City, N. J., as a contribution to the work of the Standards Committee; received April 22, 1940.

black lacquer or may be a triangle of black paper or film cemented on the track. The same result can be accomplished by punching a triangular hole in the negative before printing."

In the Transactions of our Society of May, 1929, appeared an additional part of the definition, which was deleted from the 1931 version: "the frequency of the diaphragm movement thus caused being below the threshold of audibility, no sound is heard."

In the sound-head of a reproducing system a light-beam scans the film as the film passes by the light-beam. Since the photocell of the sound-head is responsive to light variations and the system reproduces as sound the variations in the light that occur at an audible rate, any variation at an audible rate other than the intended variation will produce undesired sound from the loud-speakers. One obvious source of such undesired sound is that due to the scanning of a splice in a film. It was in connection with the treatment of splices that the term blooping was first applied; in recent years, however, the term has been broadened in scope until it is now applied often to the treatment of practically any sort of film transmission irregularity.

This paper will deal with the problem of blooping splices; it is essentially a résumé of data collected by means of a questionnaire sent to the various producing organizations. On behalf of the Standards Committee of our Society, the author wishes to express his appreciation and thanks to the twelve major companies who coöperated in obtaining the data. As general practice in the major studios, it can be said that, at the present time, not a single foot of original negative film is found in the release negative film used to print the release prints; all sound in a release print has been re-recorded. Due to the continual improvement in equipment and in operating skill, the amount of noise added in a single re-recording operation is today relatively so small that it is doubtful whether the difference between a print from an original negative and a print from a re-recorded negative could be observed on any except latest and newest reproducing equipments. Due to the fact that a large number of prints are needed for release, re-recording makes it possible to provide as many release negatives as desired with relatively equal quality in all.

Most studios do not use a bloop punch on original negative; this is especially true of variable-area. In the case of Columbia Pictures, who use both variable-area and variable-density, it is reported that they bloop-punch original variable-density negative but do not bloop-punch original variable-area negative. Warner Bros., on the other

hand, who also use variable-density and variable-area, do not bloop-punch original negative. Twentieth Century-Fox reports bloop-punching the original dialog negative and bloop-patching the printed bloop on the re-recording print.

It seems to be universal practice that a printing step occurs between the original negative and the re-recording print. While it has been suggested that a direct positive by means of what may be called a reversed optical image (maximum slit exposure for zero modulation) is suitable for originals, no studio has adopted this as general practice.

We now come to the re-recording print; here is where the greatest divergence in practice occurs. There are four types of print bloops in common use:

(*1*) Printer fog bloop.
(*2*) Sprayed stencil bloop.
(*3*) Bloop patch.
(*4*) Hand-painted bloop.

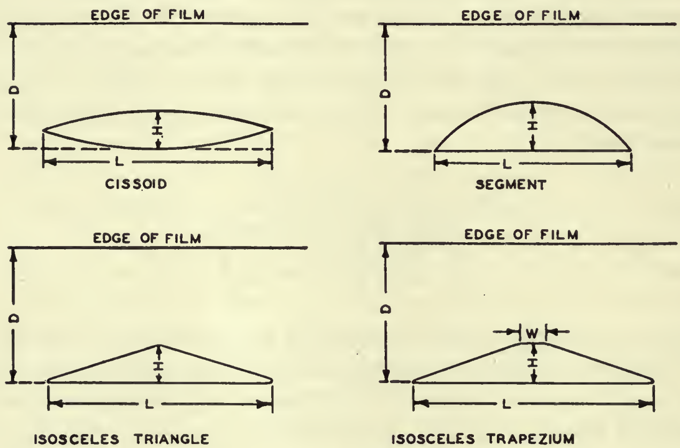
The hand-painted bloop for the most part seems to be used where either a bloop of a special size is required or where a bloop of one of the other types did not "take." Opinion on the effectiveness of the various methods varies; Columbia Pictures reports that the fog bloop which was originally developed for use with single variable-area tracks, "is the only method of blooping variable-area tracks known to us which is completely satisfactory. All the other methods which we have tried fall a little short of complete satisfaction." Twentieth Century-Fox, on the other hand, punches dialog negative and then bloop-patches the re-recording print of the dialog negative, whereas their dubbed dialog, effects, and some music tracks are assembled using a diagonal splice without either bloop punches or patches. Probably the best way to summarize is to say that each studio has "standardized" on the method which worked out best in that particular studio.

In the case of release negatives, blooping is not a problem, since practically all studios re-record the release negative in a single piece. Warner Bros., for example, reports that splices occur only due to a recut, accidental damage to the negative during release printing or for censor cuts.

Splice widths vary; in the original sound negative the reported widths are in the range from 0.50 to 0.85 inch. The width of the splice in the re-recording print is substantially the same; where splices

occur in the release negative, they are of the same width also. In all these cases, most splices reported are in the direction of the smaller size rather than the larger. In release prints, where splices occur, the reported widths are larger; most of the splices being about 0.150 inch.

Fig. 1 shows the common types of bloops in use. The earliest types were the triangle, used on variable-density, and the segment,



MEASURED DIMENSIONS.

	35 MM								16 MM
	WE3	PAR	WE 2	RCA I	P I	P 2	M I	M 2	WE-16
L	.330"	.355"	.560"	.550"	.580"	.740"	.875"	.9685"	.355"
℄	.257	.271	.250	.243		.235		.2435	.060
H	.085	.088	.115	.085	.065	.090	.156	.126	.090
W	.065						.156		.055
D	.300	.315	.308	.285		.280	.305	.306	.105

FIG. 1. Bloop punch data.

used on variable-area. Chronologically, the trapezium type followed; an improvement in both triangle and trapezium types was made by rounding the corners of the punchout holes to (*1*) increase the mechanical strength of the film at the corners; and (*2*) to reduce the amount of dirt and lint picked up by the film. The cissoid type of bloop was used in connection with symmetrical variable-area tracks. All these bloops are for single-track films; other special bloops are used for push-pull.

While originally the triangle and the trapezium types were used exclusively for variable-density and the segment type used for variable-area, today the use of a particular type of punch is not limited to a particular type of sound-track.

The lengths used vary from 0.330 inch, which seems to be the shortest, to 0.9685 inch which is the longest regularly used. If there is an "average," a length of 0.500 inch may be said to represent "average" practice. The Goldwyn Studio uses the short dimension; Metro-Goldwyn-Mayer uses the long dimension; Warner Bros. uses the "average." A ratio of almost 3 to 1 in length is rather difficult to justify from purely the sound standpoint; possibly the question of equipment maintenance and the care with which splices are made are the controlling factors. It does seem possible that this ratio can be reduced without adversely affecting the resultant film.

The centerline dimension is a derived dimension; it is equal to the dimension D minus one-half H. In measured samples, the centerline dimension varies from 0.235 to 0.271 inch. "Average" practice, as is to be expected, is represented by the 0.243-inch dimension, the standard location for the sound-track centerline. Inasmuch as our limit on sound-track centerline variation is only 0.002 inch, some explanation of the wide variation in the "derived" centerline measurement should be made. As no explanation of this variation was given in any of the replies to the questionnaire, the author will appreciate receiving whatever explanations there may be so that this material can be included in the Standards Committee records. For the present, the only assignable explanation is that it is either not considered important or that the deviation has not been observed.

Some quotations from the replies to the questionnaire are interesting:

"Studios recording their originals on push-pull generally used some form of bloop because the push-pull cancellation was not complete.

"The diversity of tracks and methods is so great that I doubt whether a standard for general use could be arrived at. On the other hand, it seems desirable that a standard bloop for release prints be worked out and we shall be glad to work with you toward this end."

Another quotation:

"Blooping re-recording prints is not a serious problem with class B push-pull re-recording as a good splice will not reproduce."

There is one other point on which there is a degree of agreement; splices are not generally blooped where there is modulation; blooping is done only where there is no modulation. This is particularly true if background effects or noise or other sound is present sufficient to mask the splice noise. Those who have used the diagonal splice seem to be in fair agreement that it is preferable where a bloop will not be used.

It can fairly be said that at the present time there is little or no difficulty with bloops in the product of the major Hollywood studios. Each studio has more or less independently arrived at some rule-of-thumb solution to its particular problem; and we can say that the solutions are effective. At the present time the criteria are empirical; listening is relied upon to a very great extent; the peak volume indicator is also used. What has "worked" in one studio, often has not "worked" in another. Release prints and release negatives are relatively free of splices and therefore the blooping problem remains within the producing studio and is not a cause for concern in distribution.

On behalf of the Standards Committee of our Society, the author will be glad to receive further comments and information on this subject. Especially desired are the following:

(*1*) Samples of blooped films of the various types properly identified as to use. Acknowledgment is herewith made of the receipt of much informative material of this nature.

(*2*) Photographs, drawings, or sketches of the apparatus and devices used to make the bloops. This is especially true of the fogging bloop equipment and the stencil-airgun equipment. A description in detail of the technic is especially desired. Please submit material suitable for publication, as we do not have on record descriptive material on the equipment and technics involved.

(*3*) Any information concerning which equipments and technics are available for the free use of the industry and which are patented.

This report has dealt with the problem as it relates to 35-mm film. At the present time, 16-mm practice is not sufficiently well crystallized to provide "average" practices. At the present time, the use of a 16-mm negative punch is not recommended on 16-mm sound-track negatives due to the physical weakening of the splice. Since the trapezium type of punch produces the least 16-mm splice weakening, it is ordinarily used where a negative punch is indicated.

There is almost complete agreement upon several points:

(*1*) The punch used should be sharp and produce a clean-cut hole. This can be checked under a microscope and by observing the printed blooped splice.

(*2*) Most punches in use are not sharp.

(*3*) The punch should not measurably weaken the splice.

(*4*) There is little or no trouble with bloops in the theater when an unspliced print is used.

DISCUSSION

MR. ROBERTS: Very often there is a double white line due to the masking effect of the top and bottom edges of the negative. Any cut in a film produces two edges due to the finite thickness of the film. These edges produce shadows, the separation of which depends upon the angularity of the printing beam. The effect is governed by the degree of collimation of the printing light.

Mr. Offenhauser said that bloops are primarily a concern of the studio. Laboratories must often use bloop punches and they are not entirely satisfactory. It has been our experience that most sound negative rips occur at these bloop punches. They break in printing machines or automatic rewinders and peel the film back very nicely.

MR. HOVER: I think that the projection profession as a whole would prefer that there be no attempt at blooping. It would save the projectionist a lot of time in examining every print, especially first-run prints, which are the worst offenders. In the laboratories or wherever there is assembly work, the blooping is so carelessly done that the manager of the average first-run house insists that his staff examine the first-run prints and check the patches. The second-run prints have usually had someone else check them.

MR. RYDER: There may be reason for complaint at times, but I will say that the laboratory and the exchange groups are making a sincere effort, more now than ever before, to take care of just such difficulties.

MR. HOVER: The worst case I have come across so far required spending an entire evening in inspecting a laboratory release of *Gone with the Wind.* Every part had to be recut and replaced.

MR. CRABTREE: Do you prefer an applied bloop patch or an ink patch? Do the patches peel away, and, if so, what is the objection to the ink patch?

MR. HOVER: Since my work has been largely with first-run prints, we have had little trouble with the applied patch. I assume that difficulty would arise in subsequent runs due to aging or wear. The difficulty with ink is that under the heat it tends to develop fine, wrinkled lines.

MR. RYDER: There are many problems in the studio that are not obvious; for instance, if we are cutting from a light negative to a dark negative, we use a longer bloop than when we cut together two relatively well-matched negatives. If we have to re-splice due to recutting, we increase the length of the bloop.

In cases where it is necessary to establish widely different print densities on either side of the splices, it is desirable to use a longer bloop as the short bloop will normally thump in reproduction.

We are encountering additional bloop difficulty with our fine-grain film stocks; thus far the best answer has been to photo-bloop the prints in line with the procedure commonly used in conjunction with variable-area recordings.

OPTIMUM LOAD IMPEDANCE FOR TRIODE AMPLIFIERS EMPLOYING FEEDBACK*

BURTON F. MILLER**

Summary.—*The apparent plate-resistance of vacuum-tubes employed in inverse feedback amplifier stages is shown to be a function of the degree of feedback employed. Equations for predicting the optimum value of amplifier load impedance for maximum undistorted power output are derived, and the necessity for properly building out the amplifier load circuit is demonstrated. A basic circuit, employing a combination of two feedback elements is indicated, which permits securing the maximum undistorted power output from an amplifier stage while maintaining proper impedance relationships between amplifier and load circuits without the use of building-out resistors.*

The nature and degree of improvement in amplifier performance which may be obtained through the application of negative feedback has previously been described in a number of excellent papers. In none of these, however, does sufficient consideration appear to have been given to the choice of optimum load impedance for the final stage of such amplifiers. It is the purpose of this paper to outline briefly the manner in which the apparent plate resistance of the output amplifier tube varies with the degree and type of feedback employed, to determine the optimum value of plate load impedance, and to indicate means of simultaneously matching the impedance of the amplifier plate circuit and load circuit properly. Consideration will be limited to those cases in which the output tube of the amplifier is operated as a triode.

The manner in which the apparent plate resistance of a tube varies with the amount and type of feedback employed is readily demonstrated by consideration of the circuit of Fig. 1. In this circuit, a generator of alternating voltage E is inserted in the plate circuit of a simple amplifier in place of the normal load impedance. Two types of feedback have been indicated as being operative in this circuit; the first of these depends upon the introduction of a fraction of the voltage

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 15, 1940.

** Warner Bros. First National Studios, Burbank, Calif.

appearing in the tube plate circuit into the tube grid circuit through the medium of the branch circuit r_1, r_2 and C. This type of feedback has occasionally been termed "constant-voltage" feedback, since it acts in such a manner as to tend to maintain a constant voltage across the load impedance in the tube plate circuit. A second source of feedback voltage is provided by the cathode resistor, r_c. The voltage introduced in the amplifier grid circuit through r_c acts in such a manner as to tend to maintain the current through the load circuit at a constant value, and for this reason feedback introduced through the medium of an impedance element common to both plate and grid circuits is sometimes referred to as "constant-current" feedback.

The reactance of the capacitance C in Fig. 1 will be assumed negligibly small compared to the sum of the resistances r_1 and r_2; furthermore, the sum of these two resistances will be assumed high compared to the plate resistance of the tube and the value of r_c. Since no consideration is being given here to the generation of distortion in the amplifier, considerable simplicity of form is gained with no loss in generality by assuming the tube plate current to be expressed by a linear function of the grid and plate voltages. The equation for tube plate current is therefore written in the form

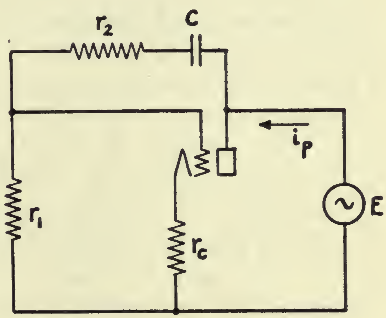


FIG. 1. Simple diagram showing feedback circuits.

$$i_p = \frac{\mu e_g + e_p}{r_p} \tag{1}$$

where

i_p is the instantaneous value of plate current.
μ is the tube amplification factor.
e_g is the instantaneous value of tube grid voltage.
e_p is the instantaneous value of tube plate voltage.
r_p is the plate resistance of the tube.

From Fig. 1,

$$e_p = E - r_c i_p \tag{2}$$

and, setting the feedback factor

$$\beta = -\frac{r_1}{r_1 + r_2}$$

the minus sign being employed to conform with common usage of the term β, the grid voltage becomes

$$e_g = -(\beta E + r_c i_p). \tag{3}$$

Substituting *2* and *3* in *1*, and solving for i_p,

$$i_p = \frac{E(1 - \mu\beta)}{r_p + r_c(1 + \mu)} \tag{4}$$

The apparent plate resistance of the tube is defined by the ratio e_p/i_p, and from *2* and *4* this value is found to be equal to

$$r'_p = \frac{r_p + \mu r_c(1 + \beta)}{1 - \mu\beta} \tag{5}$$

It should be noted that the value of apparent plate resistance of the tube given by equation *5* does not express the total impedance present in the tube plate circuit, but indicates that portion of it which may legitimately be associated with the amplifier tube. In the case of the circuit under analysis, the total resistance of the plate circuit is evidently equal to the sum of r'_p and r_c.

Consideration of equation *5* reveals that if the feedback factor β be set equal to zero, thus leaving only "constant-current" feedback, the action of the cathode resistor tends to increase the apparent plate resistance of the tube above its normal value r_p by an amount equal to μr_c. On the other hand, if the cathode resistor be set equal to zero and β be given a finite negative value, the action of the "constant-voltage" type of feedback has the effect of reducing the apparent plate resistance of the tube below its normal value by the factor $1/(1 - \mu\beta)$. If both types of feedback are employed simultaneously, the apparent plate resistance of the tube may be equal to, greater than, or less than its normal value.

In many cases it is desirable to introduce the feedback voltage βE at a point one or more stages of amplification ahead of the output tube of the amplifier. If, under such conditions, a total voltage amplification A exists between the point of introduction of the feedback voltage and the grid circuit of the output tube, it may readily be shown that the apparent plate resistance of the output tube is equal to

$$r'_p = \frac{r_p + \mu r_c(1 + \beta A)}{1 - \mu\beta A} \tag{6}$$

Having thus briefly treated the variation of apparent tube plate resistance with the type and degree of feedback action employed, attention is now directed to consideration of the manner in which the

apparent plate resistance of the tube employed in a power amplifier stage affects the values of those circuit components associated with the output circuit of such an amplifier. Numerous earlier papers devoted to the subject of audio-frequency amplifier design have pointed out that the maximum value of "power amplification" from a given amplifier stage is secured when the plate load impedance is made equal to the differential plate resistance of the tube employed. The expression "power amplification" as here used is taken as the ratio of plate circuit power output of an amplifier stage to the required grid circuit driving power. In general, it may readily be shown that, regardless of the type or degree of feedback employed, maximum power amplification is secured when the amplifier load impedance is made equal to the sum of the apparent plate resistance and the cath-

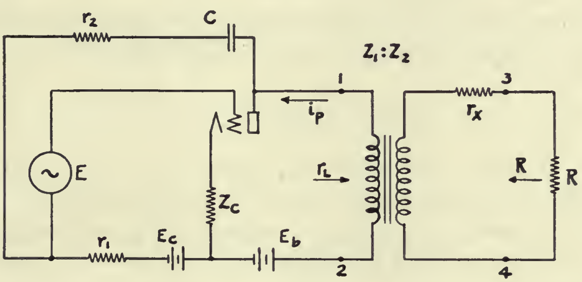


FIG. 2. Generalized feedback circuit.

ode circuit resistance r_c. It is not generally true, however, that the maximum value of undistorted power output is obtained from the amplifier for this condition of impedance matching. Furthermore, it may be assumed that in the normal recording channel, and incidently in many other amplifier services, the degree of power amplification obtained in a power output stage is of quite secondary importance when compared to the value of undistorted power which may be derived from the amplifier.

If no restrictions are placed on the value of output impedance exhibited by the power amplifier, the optimum value of load impedance may be calculated in the following manner: The generalized circuit indicated schematically in Fig. 2 indicates an amplifier stage employing both "constant-voltage" and "constant-current" feedback elements. The tube plate circuit is coupled to the load resistance R, and a "building-out" resistance r_x, through a transformer of impedance

ratio $Z_1:Z_2$. For the present analysis, the value of r_x will be set equal to zero. Then the load impedance appearing in the amplifier plate circuit is equal to

$$r_L = \frac{Z_1}{Z_2} R \tag{7}$$

A linear tube plate current characteristic as given by equation *1* will again be assumed. For the sake of simplicity it will be further assumed that the cathode circuit impedance Z_c is of such character as to present zero resistance to continuous currents, and an equivalent resistance r_c to alternating currents. Similarly, the plate circuit load impedance appearing between the terminals *1* and *2* will be assumed to present zero resistance to continuous currents, and an effective resistance r_L to alternating currents only. Then, if E_c and E_b designate the grid bias and plate battery potentials, respectively, the continuous component of plate current is given by

$$i_{p_0} = \frac{\mu E_c + E_b}{r_p} \tag{8}$$

the term E_c being presumed to carry its own sign of polarity. Likewise, if E represents the peak a-c voltage impressed in the tube grid circuit, the peak value of the alternating component of plate current is equal to

$$i_{p_1} = \frac{\mu E}{r_p + (1 + \mu)r_c + (1 - \mu\beta)r_L} \tag{9}$$

where the feedback factor β is again equal to $-r_1/(r_1 + r_2)$ and the reactance of C is neglected.

It is now presumed that grid current flow must be avoided to prevent distortion of the grid voltage wave form, so the maximum positive value of the grid exciting voltage E must be limited to such a value that the grid never attains positive potentials with respect to the cathode.

The maximum instantaneous grid voltage is equal to

$$E + \beta r_L i_{p_1} - r_c i_{p_1} + E_c$$

Setting this quantity equal to zero, the maximum permissible positive value of E is given by

$$E(\max) = (r_c - \beta r_L)i_{p_1} - E_c \tag{10}$$

Substituting *10* in *9* gives the maximum permissible value of alternating plate current as

$$i_{p_1}(\max) = \frac{-\mu E_c}{r_p + r_c + r_L} \tag{11}$$

Thus far it has been assumed that the plate current characteristics of the tube employed were truly linear. This is, in any practical case, only approximately true over a limited range of tube plate current, and it is usually necessary to limit the minimum instantaneous value of plate current to some arbitrary value i_m in order to avoid excessive distortion due to curvature of the plate current characteristic. The value of i_m is obviously equal to

$$i_m = i_{p_0} - i_{p_0}(\max) \tag{12}$$

Substituting equations *8* and *11* in *12*, the optimum value of the quantity μE_c is found to be

$$\mu E_c(\text{opt.}) = -\frac{(r_p + r_c + r_L)E_b - r_p(r_p + r_c + r_L)i_m}{2r_p + r_c + r_L} \tag{13}$$

Substituting *13* in *11*, the maximum permissible value of alternating plate current is given by

$$i_{p_1}(\max) = \frac{E_b - r_p i_m}{2r_p + r_c + r_L} \tag{14}$$

The average power delivered by the tube to the load circuit is equal to

$$P_0 = \frac{1}{2} i^2{}_{p_1} r_L \tag{15}$$

If the value of i_{p1} given by *14* be now substituted in *15*, and the partial derivative of P_0 with respect to r_L be taken and equated to zero, the solution of the resulting equation for r_L leads to a value which insures the maximum possible power output from the amplifier. This optimum value of r_L is, in fact, given by

$$r_L(\text{opt.}) = 2r_p + r_c \tag{16}$$

If $r_c = 0$, the optimum load impedance is equal to twice the value of the normal plate resistance of the tube, a relationship which has long been employed in amplifier design work.

Equation *16* above has been derived with no general or implied limitations other than the assumption of a linear plate current characteristic over a limited range of values of tube plate current, the restric-

tion on grid voltage swing to such values that the grid never attains positive potentials with respect to the cathode, and the assumption that the plate current will not be permitted to drop below an arbitrary minimum value, i_m. It is of interest to note that the optimum value of load impedance is quite independent of the value of feedback employed, except in so far as "constant-current" feedback is introduced through the medium of r_c. Since the latter factor is usually small compared to the value of the quantity $2r_p$ under any normal conditions of amplifier operation it may generally be stated that the optimum load impedance is independent of the degree and type of feedback employed.

There are many conditions of amplifier operation in which the degree of impedance matching between the amplifier output circuit and the load circuit is of little or no consequence. On the other hand, the proper functioning of certain types of load circuits is predicated upon a condition of relatively close impedance matching between the amplifier output and the load circuits. Since the designer of an amplifier can seldom be fully informed regarding all the possible applications of a given amplifier, it is generally desirable that amplifiers be so constructed as to deliver a maximum value of undistorted output power into a load whose impedance closely matches that of the amplifier output circuit.

It was demonstrated in the first portion of this paper how the apparent plate resistance of a triode is dependent upon the type and degree of feedback employed. Reference to Fig. 2 indicates that when r_x is equal to zero, the amplifier output impedance as measured at the output terminals *3* and *4* will, in the general case, be given by the expression

$$r_0 = \frac{Z_2}{Z_1} (r'_p + r_c) \tag{17}$$

while the load impedance presented to the tube plate circuit is given by equation 7. Now, it is manifestly impossible to choose an output transformer ratio such that r_L of equation 7 takes on the optimum value indicated by *16*, while at the same time the amplifier output impedance r_0 takes on the value of the load resistance R, unless both r_p and r'_p are identically equal to zero. Therefore, if a condition of impedance match is required between the amplifier output circuit and the load circuit, it becomes necessary to introduce an appropriate resistance element either in series or in parallel with the true load resistance in the amplifier output circuit. Since constant-voltage feed-

back is far more frequently employed than constant-current feedback, and since equation *5* indicates that when β is given negative values the apparent plate resistance tends toward lower values than the true plate resistance, consideration of the requirements of impedance matching and simultaneous maximizing of the useful amplifier power output will here be restricted to those cases in which r'_p is equal to, or less than, twice the normal value of r_p. Under this condition r_x will always be required to appear in series with the true load resistance.

If the amplifier be assumed to be delivering a total output power P_0 into its load circuit, the useful power P_{0L} delivered to the load resistance R is equal to

$$P_{0_L} = \frac{R}{R + r_x} P_0, \tag{18}$$

where P_0 is given by equation *15*.

Setting the impedance ratio Z_1/Z_2 of the output transformer equal to N^2, the load impedance appearing in the amplifier plate circuit is given by

$$r_L = (R + r_x)N^2 \tag{19}$$

The requirement of impedance match between the amplifier output circuit and the load resistance is expressed by

$$R = r_x + \frac{r'_p + r_c}{N^2} \tag{20}$$

From *20*,

$$r_x = R - \frac{r'_p + r_c}{N^2} \tag{21}$$

Substituting *21* in *18*,

$$P_{0_L} = \frac{N^2RP_0}{2N^2R - (r'_p + r_c)} \tag{22}$$

Substituting *21* in *19*

$$r_L = 2N^2R - (r'_p + r_c) \tag{23}$$

The maximum value of the alternating component of plate current is found by substituting *23* in *14*, and is equal to

$$i_{p_1}\,(\max) = \frac{E_b - r_p i_m}{2(r_p + N^2R) - r'_p} \tag{24}$$

Substituting this value of i_{p_1} in the expression for P_0 given by *15*, and

the resulting value of P_0 in equation *22*, the following equation is obtained for the value of the useful power delivered to the load resistance R: namely

$$P_{0_L} = \frac{N^2R}{2}\left[\frac{E_b - r_pi_m}{2(r_p + N^2R) - r'_p}\right]^2 \tag{25}$$

Taking the partial derivative of P_{0_L} with respect to N^2, and equating the resulting expression to zero, the optimum value for the transformer impedance ratio is given by

$$N^2 = \frac{2r_p - r'_p}{2R} \tag{26}$$

Correspondingly, the optimum value of r_x is given by

$$r_x = R\left[1 - \frac{2(r'_p + r_c)}{2r_p - r'_p}\right] \tag{27}$$

The value of r_x as given by *27* is positive for all values of r'_p between the limits of zero and $2(r_p - r_c)/3$, and the values of N^2 given by *26* may be employed for the same range of values of r'_p. Throughout this range the useful power output is equal to

$$P_{0_L} = \frac{(E_b - r_pi_m)^2}{16(2r_p - r'_p)} \quad . \quad r'_p \leqq \frac{2(r_p - r_c)}{3} \tag{28}$$

When r'_p is greater than $2(r_p - r_c)/3$, r_x must be set equal to zero, since negative values of this resistance would imply that r_x were to be regarded as a source of power. When $r_x = 0$, the proper transformation ratio for an impedance match is given by

$$N^2 = \frac{r'_p + r_c}{R} \tag{29}$$

and the effective load resistance in the tube plate circuit is equal to $r'_p + r_c$. Substituting *29* in *25*, the following expression for P_{0_L} is obtained, and is valid under all conditions when r_x is equal to zero.

$$P_{0_L} = \frac{(r'_p + r_c)}{2}\left[\frac{E_b - r_pi_m}{2r_p + r'_p + 2r_c}\right]^2 \tag{30}$$

This expression attains its maximum value when $r'_p = 2r_p$, as may readily be verified by differentiating with respect to r'_p, equating the derivative to zero, and solving for r'_p.

From time to time commercial amplifier designs have appeared on the market in which a series building-out resistor was employed in the amplifier output circuit, even though no feedback was employed in the amplifier. The designers, in justification of this step, have

pointed out that greater undistorted power output could be obtained when such building-out resistors were employed than could be secured in their absence. The truth of this statement evidently hinges on the degree of distortion which is considered tolerable, and on the departure of the actual tube characteristics from the simple linear characteristic assumed throughout this paper. That the use of the building-out resistor can not be justified if the tube characteristic is linear, or nearly so, will be evident from the following considerations.

In the absence of feedback, the apparent and true plate resistances assume identical values. The resistance r_c, in the sense employed in this paper, must be assumed equal to zero, the necessary bias potential for the tube being supplied by the source E_c. Then, setting $r'_p = r_p$, and $r_c = 0$, the maximum undistorted power output of the amplifier for $r_x = 0$ is given by substituting these values in equation *30*, and is equal to

$$P = \frac{(E_b - r_p i_m)^2}{18 r_p} \tag{31}$$

Now let it be assumed that a building-out resistor is employed, and that the impedance ratio of the output transformer is so chosen that the load resistance presented to the tube plate circuit is equal to $2r_p$. Accordingly,

$$N^2(R + r_x) = r_L = 2r_p \tag{32}$$

For a condition of matched impedance between amplifier and load,

$$R = \frac{r_p}{N^2} + r_x \tag{33}$$

Substituting the value of r_x given by *33* in *32*, and solving for the optimum transformation ratio,

$$N^2 = \frac{3r_p}{2R} \tag{34}$$

From *14*, the maximum value of alternating plate current would be

$$i_{p_1}\ (\max) = \frac{E_b - r_p i_m}{4r_p}$$

and the substitution of this value in *15* would indicate a total power output from the amplifier equal to

$$P_0 = \frac{(E_b - r_p i_m)^2}{16 r_p} \tag{35}$$

Employing *33* and *34*, it is found that

$$\frac{R}{R + r_x} = \frac{3}{4} \tag{36}$$

The useful power actually delivered to the load resistor R is therefore equal to

$$P_{0_L} = \frac{3(E_b - r_p i_m)^2}{64 r_p} \tag{37}$$

A comparison of equations *31* and *37* immediately indicates that the use of the building-out resistor in conjunction with an amplifier employing no feedback results in a lower value of useful power output

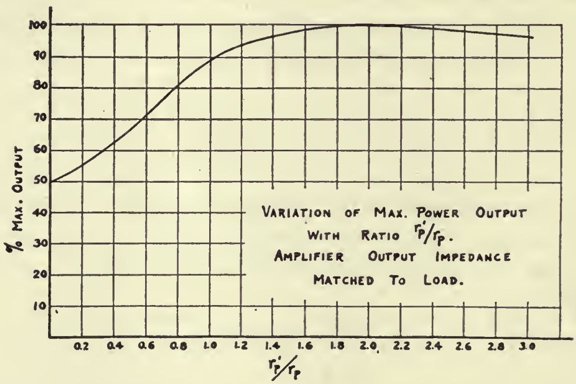


FIG. 3. Variation of maximum power output with the ratio r'_p/r_p.

than can be obtained by directly matching the impedance of the load circuit to that of the amplifier plate circuit. Should it be determined, experimentally or otherwise, that the actual undistorted power output is greater when the building-out resistor is employed in amplifiers operating without feedback, it must be concluded that factors other than those considered in this paper are operative.

Turning now to consideration of amplifiers employing relatively high values of constant-voltage negative feedback, equation *5* indicates that the apparent tube plate resistance may be reduced to very low values as compared to the value of r_p. Under this condition, the value of the building-out resistor r_x, as given by *27*, approaches the value of the load resistance R. On the other hand, if a sufficient degree of constant-current feedback be employed, either in conjunction

with or in the absence of a fixed amount of constant-voltage feedback, the value of the apparent tube plate resistance may be made equal to twice the value of the normal tube plate resistance. Under this condition, the value of r_x should be made equal to zero, while the transformation ratio N^2 should be so chosen that a condition of impedance match exists between the amplifier output and the load circuits. The load impedance appearing in the tube plate circuit is then equal to the optimum value $2r_p$, and maximum power output from the tube is assured. Furthermore, since r_x is equal to zero, all the power output of the amplifier is delivered to the load resistor R. This condition represents an optimum then, in the sense that not only is the condition for maximum power output from the tube realized, but also that a condition of impedance match exists between amplifier and load. It must be assumed, of course, that r_c is negligibly small compared to the value of $2r_p$.

The manner in which the ratio of useful to theoretical maximum power output of an amplifier varies with the ratio $r'_p/2r_p$, under a condition of impedance match between the amplifier and load circuits, is shown graphically in Fig. 3. Data for this curve were calculated from equation *28* for all values of $r'_p \leqq 2r_p/3$, r_c being assumed negligibly small, and from equation *30* for all higher values of r'_p. It is interesting to note that as the ratio $r'_p/2r_p$ approaches zero, a maximum power loss of 3 db is incurred through the use of the building-out resistor. Simultaneously, a high degree of stability in the value of the amplifier output impedance is assured, since the greater portion of this impedance is represented by the building-out resistor.

A PRECISION INTEGRATING-SPHERE DENSITOMETER*

J. G. FRAYNE AND G. R. CRANE**

Summary.—*A densitometer employing an integrating sphere associated with a stable high-gain amplifier is described. Densities up to 3.0 are read directly on a multiple-scale logarithmic meter. Visual diffuse operation is attained by simulating average eye characteristic by inserting appropriate filters in optical path.*

Since the inception of sound recording on film it has been recognized that some form of sensitometric control of the negative and positive processing is necessary in order to obtain uniformly good results. Two instruments, the sensitometer and the densitometer, are employed in all sensitometric testing and control work. In the early stages of the sound-on-film recording art, there was much confusion due to the multiplicity of sensitometers which were then in use. This problem, however, appears to have been solved satisfactorily by the wide adoption of the Eastman II*b* sensitometer[1] which is generally conceded to be the standard in its field. The same can not be said, however, for the densitometer, as a variety of densitometers is still in use, many of which involve design features which influence the readings obtained on them. Since a great many of these instruments are of the visual type, considerable variation is found in the readings on any single instrument made by different observers. Recently there have been introduced in several laboratories physical densitometers which usually employ a photronic cell with a sensitive meter to measure the light transmitted through film, the meter being calibrated to read density. These instruments, however, are usually calibrated against strips which, in turn, have been measured on visual instruments; so that beyond eliminating the personal factor in observation, these instruments still depend on another instrument for calibration which does involve the personal factor. Also, these instruments are usually not reliable for densities greater than 1.5 due to the low cell currents. A very interesting design of photoelectric

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cell densitometer has been reported by Lindsay and Wolfe,[2] which overcomes many of the objections of the photronic cell type and which employs many features similar to those utilized in the present design.

In view of the importance of accurate determination of density for sound-on-film recording, it was considered desirable to build the instrument described in this paper to measure density of the silver deposit based only on fundamental scientific considerations and capable of calibration by some absolute method. For ease of operation, it was decided to make this instrument direct reading, thereby eliminating all balancing devices.

Theoretical Considerations.—While the problems involved in the experimental determination of density have been discussed by various authors, a brief résumé of some of the fundamental points involved are reviewed here for the benefit of those who have not had the opportunity thoroughly to scan the literature on the subject. The fundamental definition of photographic density was originally given by Hurter and Driffield,[3] as follows:

$$D = \log_{10} O = \log_{10} F_0/F_1,$$

where F_0 is the light-flux incident on the silver deposit and F_1 is the light-flux transmitted by the deposit, the ratio of these two being defined as the opacity of the deposit to the incident light. Now if the photographic silver deposit were a perfectly homogeneous layer, the measurement of its density would be a simple problem, involving as it does the measurement of the two quantities F_0 and F_1. The silver deposit, however, being granular in structure, scatters or diffuses the incident light-flux. Unless this is taken into consideration in measuring the transmitted flux, the resulting density measurement will depend on the optical constants of the measuring instrument.

Specular and Diffuse Density.—When a beam of collimated light falls on a silver image the light that is transmitted is scattered or diffused by the granular structure of the silver image. This is illustrated in Fig. 1 which uses the same graphical illustration employed by Jones.[4] In this figure the lengths of the transmitted rays are indicative of the intensity of the distribution of the transmitted light. If some light-measuring device such as the hollow sphere is placed as in Fig. 1(A), only the least scattered rays are collected, while if the same device is moved to the position shown in Fig. 1(B), all the scattered light transmitted by the film is intercepted. If the value of the light-flux measured at A is substituted in the Hurter and

Driffield equation, the resulting value of D is known as the *specular* density of the image. On the other hand, if the flux as measured at B is used, the result is known as the *diffuse* density of the silver deposit. The relation between values of diffuse and specular density was first investigated by Callier[5] and the ratio is generally known as "Callier's Coefficient." In so-called visual diffuse-reading densitometers the practice of diffusing the incident light is quite prevalent. In these instruments diffusion of the light is usually accomplished by

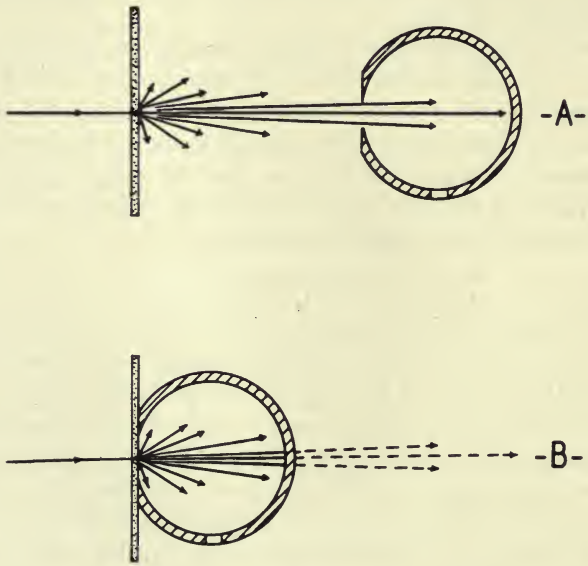

FIG. 1. Diagram illustrating (A) specular density, (B) diffuse density.

inserting a piece of opal glass between the light-source and the film deposit, the film emulsion being placed directly in contact with the smooth surface of the diffusing glass. A certain cone of transmitted diffuse light is collected at the entrance pupil of the particular optical system employed in this type of densitometer. The limitations and errors involved in the use of the so-called diffuse-reading densitometers have been discussed in detail by Koerner and Tuttle.[6] They point out that since it is impossible to obtain perfect diffusion with opal glass over a 180-degree angle, the insertion of the granular photographic deposit will tend further to scatter the incident light. As

the scattering increases with increasing density, less and less of the transmitted flux will enter the entrance pupil of the instrument, thus tending to make the readings depart from the theoretical 100 per cent diffuse condition and approach instead the specular condition described above.

Integrating Sphere Density.—The operation of the integrating sphere is illustrated in Fig. 2. A ray incident on a film sample, placed at the entrance of the sphere, is scattered by the emulsion. The scattered rays are reflected repeatedly at various angles from the in-

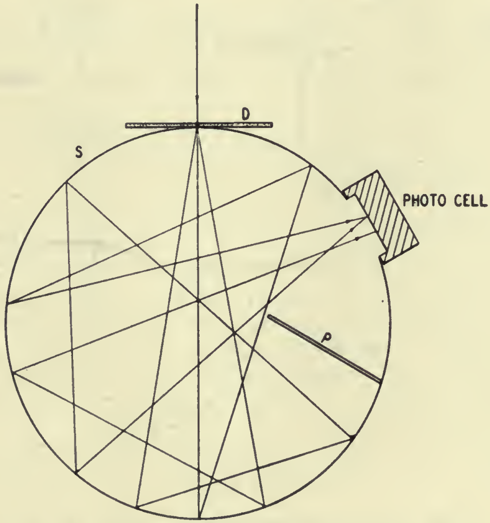

FIG. 2. Illustrating diffusing action of integrating sphere.

side wall of the sphere. This wall is coated with a highly diffuse and highly reflecting surface so that the complete inner surface assumes a uniform brightness. This brightness has been shown[7] to be directly proportional to the total flux entering the sphere. The use of the baffle P shown in the figure is to prevent any direct rays from entering the photocell from the bottom of the sphere, which tends to be highly illuminated when no film, or films of low density, are present. With the deflecting plate present the surface of the sphere assumes uniform brightness under these conditions. The current generated in the photocell is proportional to the brightness of the sphere wall and therefore proportional to the light-flux transmitted through the

film. To measure density at the sphere it is only necessary first to measure the current in the cell with no film at the sphere entrance window, and then with the film sample present. The common logarithm of the ratio of the first reading to the second reading of the cell currents will indicate the diffuse density of the silver deposit.

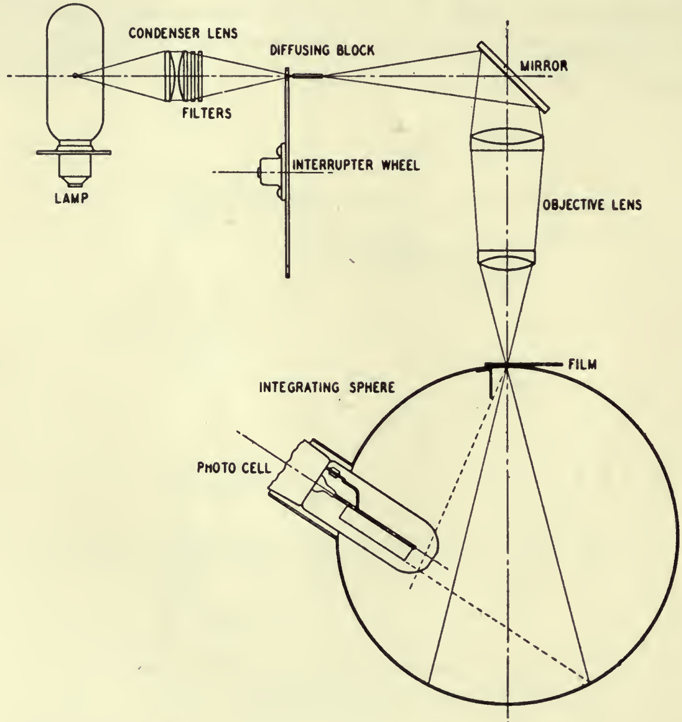

FIG. 3. Optical schematic of densitometer.

Optical Efficiency of Sphere.—The efficiency of the integrating sphere, which is determined by the ratio of the light that reaches the cell to the light that enters the sphere, is rather low. This is due to absorption of the radiation by the relatively large surface of the sphere. The general problem of the efficiency of radiation enclosures has been studied in detail by Moon and Severance,[8] and this instrument employs a method suggested by them which calls for the placing of the photocell within the limits of the sphere. This, incidentally, has been found to provide the easiest mounting of the cell

as well as meeting the requirement for providing maximum efficiency. With the arrangement of the cell shown in Fig. 3, and with a magnesium oxide diffusing surface on the inside of the sphere, an efficiency of approximately 5 per cent has been obtained. Even with this low efficiency it has been found possible as described later in the paper, by means of suitable amplification to measure densities up to 3.0 with a high order of stability.

Color-sensitivity.—The spectral sensitivity of the photocell employed with the integrating sphere is of importance in the measure-

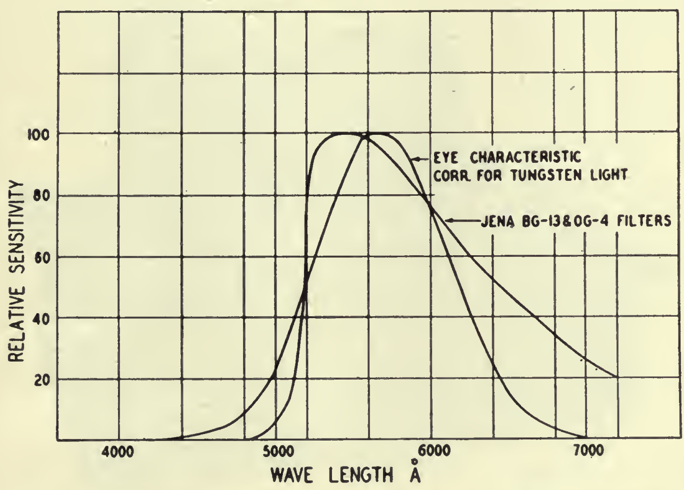

FIG. 4. Comparison of eye characteristic and effective overall spectral sensitivity of densitometer.

ment of densities which are not of the ordinary neutral gray type. For example, photographic deposits often have a definite spectral selectivity which may be due to a stain induced in the developing process or, as in the case of fine-grain films, to scattering of the shorter wavelengths by the granular deposit. If the readings of the sphere densitometer are to agree with the visual diffuse type of measurement, it is necessary that a suitable filter or combination of filters be placed in the optical path so that the resultant spectral response of the photocell simulates that of the eye. The curves in Fig. 4 show the average eye characteristic and that of the G.E. *FJ-401* photocell with Jena *BG-13* and *OG-4* filters placed in the optical beam. Both curves are corrected for tungsten light at 3100°K. It will be

noted that the two curves do not coincide exactly but this represents the best match that could be obtained with available filters of the permanent colored glass type.

Photographic Density.—Because of the spectral selectivity referred to above, the density of a negative measured visually may differ widely from the actual density as seen by the positive film in the

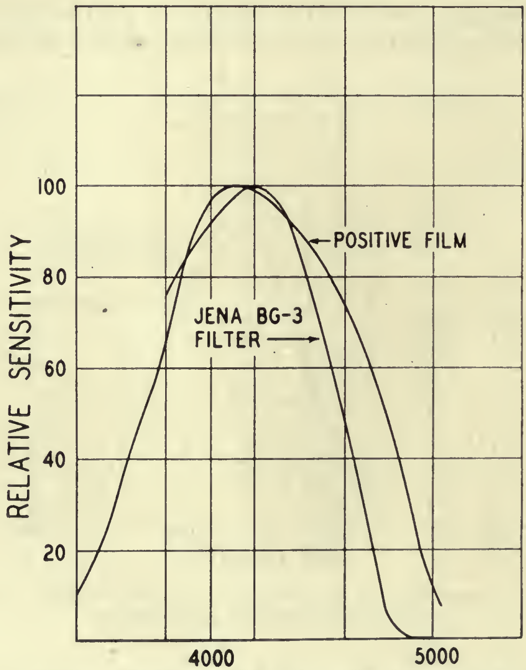

FIG. 5. Comparison of positive film and proposed spectral sensitivity for measurement of printing density; corrected for tungsten light at 3100° K.

printing process. This is due to the fact that the positive film is mainly sensitive in the blue-violet end of the spectrum. If we wish the densitometer to measure this printing or photographic density, it is necessary to filter the light falling on the cell so that the response of the latter simulates that of the positive film. Such filtering is provided by incorporating a Jena *BG-3* filter, which is shown in Fig. 5, simulating quite closely that of the positive film. There has not been sufficient experience at this time with the use of this latter type of filtering to say definitely whether it should be recommended for

measurement of negative densities. It is probably desirable in the interests of standardization to retain the visual characteristic until such time as some other standard of spectral sensitivity has been adopted for densitometric measurements.

Density Range.—In order to measure effectively the range of densities in sound photographic processes, it appears necessary to be able to read as high as 3.0. This means a range of 1000 to 1, or 60 db, in input voltage to the amplifier of the densitometer. Since it is extremely difficult to cover this range in one scale it is desirable to use

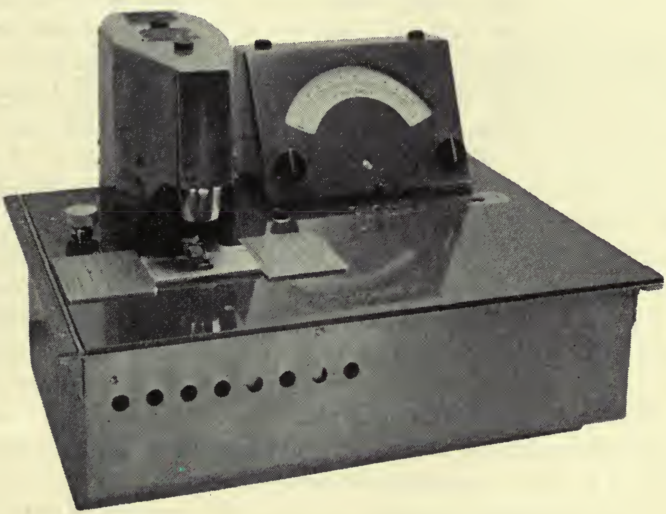

FIG. 6. Integrating sphere densitometer.

a multiple scale with three ranges of density; namely, ranges of 0 to 1.0, 1.0 to 2.0, and 2.0 to 3.0. This may be accomplished by inserting in the amplifier circuit a 40-db loss for the first range, 20-db loss for the second range, and no loss for the highest density range. The use of these loss pads is obvious when one considers the energy relationships expressed in decibels and density; namely, that the db difference of currents for two density conditions equals twenty times the density difference. For example, if I_0 and I_1 represent the current values in the photocell, corresponding, respectively, to the cases where no film is present at the aperture and where a film with a certain density is present, then from the explanation given above of the

operation of the sphere, the density of the film strip is given by the equation

$$D = \log_{10} (I_0/I_1)$$

Now the input to the amplifier corresponding to a photocell current I_1 compared to that for a photocell current I_0 when expressed as a decibel difference is:

$$\Delta \text{db} = -20 \log_{10} (I_0/I_1) = -20 (D_1 - D_0)$$

Thus we see that the decibel difference is 20 times the density difference. It follows that a maximum density reading of 1.0 at the extreme end of the first scale can also be read as 1.0 at the other end of the scale by simply increasing the grain of the amplifier 20 db.

Design.—As shown in Fig. 6, this instrument has been designed to be mounted in a table with its panel flush with the table top The head assembly and meter case are above the panel, located for maximum convenience in operation and reading. A steel case houses the sphere, amplifier, and associated equipment.

Optical System.—The optical system is shown schematically in Fig. 3. The light-source is a standard lamp with a prefocus base which is used in several sound reproducing systems. The filament is operated at a relatively low temperature to insure long life, and the current is supplied by a saturation type of voltage regulator which maintains constant current over a wide range of line voltage. Ballast lamps are also used and in locations where the line voltage variation is less than 1 volt, the regulator is not required.

The condenser lens assembly consists of a pair of plano-convex lenses whose mounting also contains the colored glass filters. The image of the lamp filament is brought to a focus on a rectangular glass block which is 50 $\times$ 200 mils in cross-section. The length of the block is chosen to eliminate completely the coil pattern of the filament at the exit. The cone of light falling on this block is interrupted by a synchronously driven interrupter wheel which gives a frequency of 600 or 720 cycles per second on a power supply of 50 or 60 cycles respectively. The light from the glass block is reflected downward by an aluminum-coated first-surface reflecting mirror to the objective lens, which brings the exit face of the block to a focus at the film plane. This lens is a well corrected system of high aperture which operates at a 2 to 1 reduction and gives a sharply defined spot of light of 25 $\times$ 100 mils at the film plane. Any size or shape of spot could be used, but this value was chosen to measure conveniently one-

half of a 100-mil push-pull track as well as being suitable for general sound-track or sensitometric measurements.

The film is placed emulsion side downward in contact with the surface of the integrating sphere, which receives all the light passing through the film in the manner previously described. As shown in Fig. 3, a baffle is provided to prevent any direct light-rays from the film from falling directly on to the photocell element. The cell placement was likewise chosen so that the first reflection from the brightly illuminated lower area of the sphere does not fall directly on the sensitive cell surface.

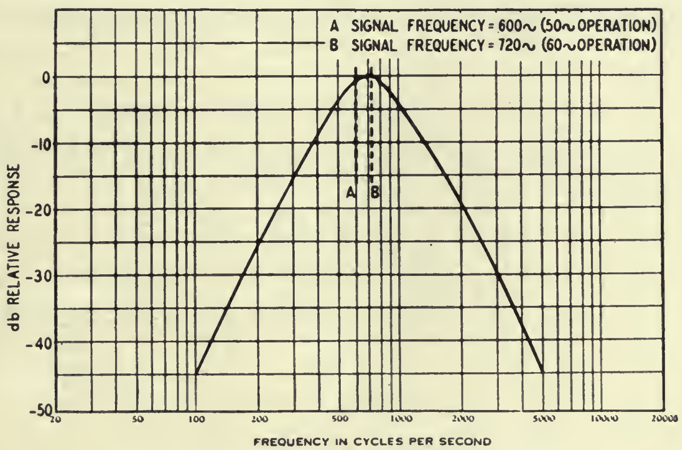

FIG. 7. Frequency characteristic of amplifier.

The aperture in the sphere affords but slight clearance over the dimensions of the rectangular scanning beam and, due to its relatively high intensity, there is no effect on the reading due to external a-c light or daylight of ordinary intensity. In addition, the amplifier characteristic discriminates against power frequency components as shown by Fig. 7.

The several units of the optical system are mounted in a rigid aluminum alloy casting with a removable cover which is designed to provide adequate ventilation. The motor used to drive the interrupter wheel has been chosen to have a long life, and a special mounting is provided to minimize vibration. The sphere is mounted beneath the panel and has suitable adjustments for vertical and lateral positioning.

Amplifier.—To raise the output from the photoelectric cell to a convenient level for measurement, a high-gain, stable amplifier is required. To attain the order of accuracy required, the gain of this amplifier must be extremely stable with respect to temperature and line-voltage changes over a reasonable range. In addition, the gain must be constant over a wide range of signal level, with the lowest possible noise, which includes cathode emission noise in the first stage, photocell hiss, and a-c pick-up. The output meter circuit must be such that the meter can not be damaged when a signal 40 db above meter full scale is applied, for example, as when a density of 3.0 is suddenly removed from the gate. In addition, the reading accuracy of the instrument must not be affected by changing any amplifier tube.

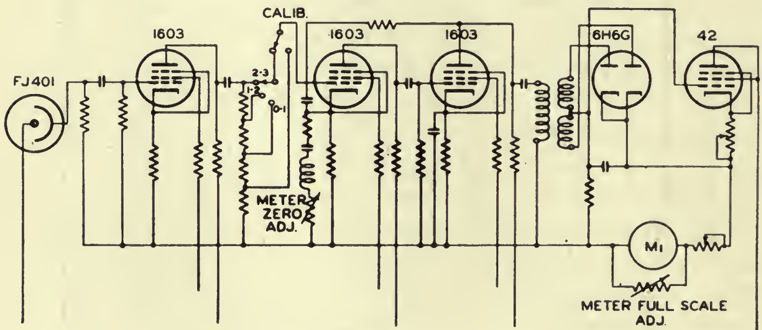

FIG. 8. Simplified schematic of amplifier.

To meet these requirements with an economy of circuit elements, the amplifier circuit shown schematically in Fig. 8 was adopted. Due to the relative inefficiency of the intergrating sphere, the output from the photoelectric cell is approximately -60 db/0.006 watt with no film, or zero density, which is reduced to a level of -120 db when measuring a density of 3.0. Because of these low signal levels, the input circuit is designed for a high signal-to-noise ratio, and a 600 to 720-cycle selective circuit is employed in the feedback path to discriminate against noise components. In addition, several condenser values have been chosen to reduce power supply hum and the higher components of tube and photocell noise. By these means a noise level of -150 db/0.006 watt or lower has been attained, which provides an ample margin for accurate measurement of density up to 3.0.

The output of the photocell is picked up across a high-impedance coupling circuit and applied to a stage of amplification which uses a low-noise pentode tube for high gain and has ample cathode feedback for gain stability, linearity, and high signal-to-noise ratio. As previously mentioned, it was decided to cover the density range in three scales, which amounts to a signal range of 20 db per scale. A key on the panel operates on a simple voltage-divider in the output of the first tube, as shown in Fig. 8, to increase the gain of the amplifier by 20 and 40 db relative to the *0–1* range. A push-button on the same voltage-divider reduces the gain by 20 db for calibration purposes.

Two more pentode stages further amplify the signal and employ feedback from the plate of the second to the cathode of the first. In series with the resonant circuit is a variable resistance which serves as a gain control for adjustment of the zero density reading of the indicating meter, as described below under *Operation.* The output circuit to the meter is similar to that employed in certain volume indicators, using a twin diode rectifier and a power pentode connected as a triode for the output tube. The output of this tube is made completely degenerative to increase stability. A part of the cathode resistance voltage drop is used to apply a threshold voltage to the diode. A ballast lamp is included in the heater circuit of the output tube to increase its stability with normal changes in supply voltage.

The meter settings, which are dependent on amplifier gain and plate current of the last tube, exhibit good stability over long periods of time, with the exception of a slight drift during the first few minutes of operation. Even during this period, errors may be avoided by occasionally checking the end points of the scale.

Meter.—Since density is fundamentally a logarithmic function, any attempt to indicate density using linear elements will result in an uneven scale on the indicating device with crowding of the scale at the higher density values. To facilitate observation of the scale, therefore, it is desirable either to make an amplifier with a logarithmic response or to provide a meter the deflection of which will be a logarithmic function of the current supplied to the meter. While some success has been attained in the former over a limited range, it is difficult to provide such a characteristic over a range of 60 db required to cover the density range from 0 to 3.0 and maintain sufficient stability for the required accuracy. Consequently, it was decided to have developed a special indicating meter that would approximate

the logarithmic condition referred to above. Since it had been previously determined to cover the density range of 1.0 for each scale it seemed possible that a meter with specially designed pole-pieces might give a reasonably uniform logarithmic response over this range, which corresponds to a 10 to 1 range in input current. Accordingly a special meter having a full-scale deflection of 20 milliamperes was developed by the Weston Electrical Instrument Corp., and the resulting scale may be seen in Fig. 6. A relatively large meter was chosen which provides a useful and almost linear scale approximately 5 inches long. It is illuminated by two lamps located within the meter housing, but external to the meter itself. The damping of a meter of this type is difficult to control because of the wide variation of flux-density at different scale positions, but the meter period is sufficiently high that little inconvenience is caused by the under-damped condition which exists at the left hand or *0* end of the meter scale.

Calibration.—It is desirable in a densitometer of this kind that the calibration be made in some absolute manner rather than be dependent on some other type of instrument which may have fundamental errors inherent in its design. Accordingly it was decided to make a calibration of the photocell amplifier and meter combination utilizing the inverse-square-law technic. An interrupted light-source of the same type used in the densitometer was set up so that it could be moved back and forth on an optical bench at known distances from the active surface of the photocell. Distances were then chosen so that the light-intensity on the photocell would be altered by integral decibel steps. This test was made primarily to make certain that any non-linearity occurring in the photocell over this range would be included in the overall calibration. An electrical calibration using a routine electrical transmission test method was likewise made of the amplifier and meter. The calibration determined electrically correlated so closely with that obtained by the inverse-square law that the differences were negligible. In view of these findings and because the electrical calibration can be made so easily and checked at any time where transmission measuring facilities are available it was decided to use this method exclusively for calibrating the instrument. The cell current is of the order of a tenth of a microampere so that its life should be practically indefinite. Including the errors in the instrument as well as those due to non-linear response from the photocell, the maximum probable error on the *0–1* and *1–2* ranges will not exceed 0.01 and on the *2–3* range it will not exceed 0.02. It is believed

that this degree of accuracy is ample since variations of greater magnitude may be found in present-day sensitometric practices.

Operation.—An attempt has been made to make the operation of this instrument as simple and rapid as possible. The power switch on the densitometer controls also the voltage regulator and the power supply to the amplifier, as shown in Fig. 9. To use the instrument, the end points of the scale are first adjusted. To do this, the pointer is first set to *0* by means of the left-hand knob and then to the *1.0*

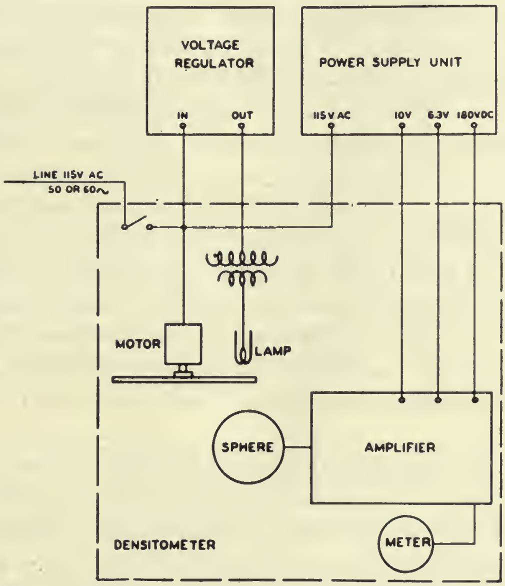

FIG. 9. Block schematic of densitometer and auxiliary equipment.

using the right-hand knob, with the push-button depressed. To make a measurement, the film is placed in the gate, emulsion side down, and the gate moved laterally to scan the area desired. The pressure spring at the gate may be swung out of the way when not wanted, but contact must be maintained between the emulsion and the sphere aperture. When the density reading exceeds 1.0, the key is thrown to the *1–2* position and 1.0 added to the meter reading, and likewise to the next scale as the density exceeds 2.0.

In an effort to facilitate the reading of sensitometer strips, guide plates have been provided with suitable markings for use with strips

made on the Eastman II*b* sensitometer or equivalent. These guide plates are used in connection with the block No. 11 index mark normally present on the sensitometer strip. This insures proper measurement at a given area of each tablet and avoids further counting to return to, or identify any tablet. In the case of printed-through strips or other strips which do not have the standard index mark at block No. 11, provision is made on the guide plate to relocate an index mark. This mark then replaces the standard index mark and is used in the same manner. While this instrument employs a film gate designed for 35-mm motion picture film, it may be readily replaced by a smooth plate for the measurement of films or plates up to 5 inches wide.

Comparison with Other Instruments.—Preliminary comparisons have been made with several other densitometers in general use at the present time. A complete survey of all types of instruments in present use appeared prohibitive due to the variety of existing types, each with somewhat different optical constants and spectral sensitivities. Consequently, comparisons were limited to a few representative types. The visual type was represented by the Western Electric *KS-6466* polarization type and the Eastman Kodak Capstaff-Purdy wedge type as read by experienced observers. Two physical densitometers were used, one being a photronic cell type and the other a photocell and amplifier type, both of which have been in general use for some time.

It was found that for neutral gray deposits, such as are found in positive sensitometric strips, close agreement was found with both visual and physical densitometers that had been calibrated carefully against visual diffuse density standards. It was noted, however, that readings on the polarization type of instrument were somewhat higher on the high-density range. In the case of the brownish colored finegrain negatives, considerable deviation was found in readings made on the visual types. This is undoubtedly due to the extreme difficulty of judging balance when the film deposit has any noticeable color. The ease and rapidity of operation of the sphere desitometer stood out in marked contrast to that of all types tested.

Conclusion.—The integrating-sphere type of densitometer described in this paper associated with a stabilized high-gain electrical amplifying system, makes it possible to read densities up to 3.0 in accordance with the Hurter and Driffield definition of density. The readings are made quickly and easily on a direct-reading rugged meter and may be made either in broad daylight or in a room illumi-

nated with ordinary a-c lamps. The personal factor is eliminated in the readings and the calibration is based only on fundamental physical laws. While the readings are made to correlate with those of visual diffuse standards by insertion of suitable optical filters in the scanning beam, any spectral sensitivity that may later be adopted may be secured by inserting the appropriate color filters.

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DISCUSSION

MR. OFFENHAUSER: Many of us are not familiar with the *FJ 401* photocell. What type of cell is it, and what are its operating limits?

MR. ALBERSHEIM: It is a gas-filled rubidium cell. Under the operating conditions in the *RA-1100* densitometer the cell characteristic is linear so that optical and electrical calibrations agree. The density limit is 3.0.

MR. KELLOGG: Is it logical to include the type of light-source or to duplicate the type of light-source, as well as the eye characteristic, in estimating visual effects; or, similarly, if you are measuring negatives, to include the type of printer light as well as the film sensitivity in the densitometer?

MR. ALBERSHEIM: Yes, the eye characteristic is somewhat affected by the light-source, but this factor was taken into account in the filter-factor shown in Fig. 4. In the case of this densitometer, the light is somewhat reddish in color, because we run an incandescent lamp at low temperature, so that it will last very long. It is easily duplicated, and we just filtered it out to approximate the eye characteristic with normal light. If we wanted to use one and the same printer light all the time, we could multiply the film characteristic with the emission characteristic of the printer light and use filters which simulate that characteristic.

MR. KELLOGG: Both factors must be taken into account.

MR. ALBERSHEIM: The more factors eliminated, the better; but we have to adjust ourselves to the requirements ot the industry, and at the present time

people are used to certain densitometers and printer factors and do not like too many changes at one time. When they have been using this densitometer for a while, and gained confidence in its consistency as a densitometer, then if they would like to eliminate one or two of the factors and change the filter characteristics, it can easily be done.

MR. ROBERTS: Is it always desirable to use the integrating sphere type of pick-up? Do you not at times want to do sensitometry as seen by the optical system of your reproducer? Is there any way you can shift your pick-up so that it receives specular light, somewhat similar to that of a reproducer?

DR. FRAYNE:* That can be accomplished if desired.

MR. KELLOGG: Can you give a figure for the estimated efficiency of the integrating sphere?

MR. ALBERSHEIM: Five per cent, in this particular sphere.

MR. KELLOGG: If you can still accomplish your diffusion, the larger the fraction of the total internal area you can make the photocell represent, the better off you are in terms of efficiency.

MR. ALBERSHEIM: Quite true; but it also reduces the perfection of diffusion. This 5 per cent is a compromise, and is about the degree of efficiency deemed necessary for stable amplification. The level for density of 3 goes down to an input of -120 db (referred to 6 milliwatts). If we had a wide-band amplifier, that would be close to noise level; but due to the fact that we have a narrow range of amplification, we still have 30 db available, with good stability. At the same time, these low intensities are a slight advantage from the point of view of linearity of the photocell. At large amplitudes the photocells are not quite linear; at low intensities they are perfectly linear, and the cell amplitude characteristic does not affect the calibration.

MR. EVANS: What is the area of the sample which is measured?

DR. FRAYNE:* The scanning on the commercial instrument will probably be of the order of 70×100 mils for standard work and be capable of being reduced to the 25×100 mils which is used in this instrument.

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* Communicated.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

RECORDING AND REPRODUCING SQUARE WAVES*

D. CANADY**

In the May, 1939, issue of the JOURNAL[1] a brief description was given of special film recording and reproducing equipment built for the Oscillograph Laboratory, Department of Psychology, Oberlin College, Oberlin, Ohio. As some interest is being manifested in sound engineering fields in the use of square waves for circuit testing, it is thought that a brief description of the associated equipment used in connection with the film recorder and reproducers will be of interest at this time.

Amplifiers.—Prior to the installation of the film equipment, direct-coupled amplifiers were designed and built under the direction of J. M. Snodgrass of the oscillograph laboratory. The basic requirements involved were that the completed system be capable of handling square waves and transients of steep wavefront. It was quite obvious that conventional transformer- or resistance-capacity-coupled amplifiers were not capable of amplifying complex wave-forms of this nature without considerable phase-shift. A successful direct-coupled amplifier developed by Snodgrass in 1932 was used as a basis for the present design. The amplifiers are (*1*) quite stable in operation over long periods of time; (*2*) noise level is low at high gain; (*3*) power output is ample for all requirements. Rigorous tests have shown that the most complex wave-forms can be amplified to high levels without distortion or phase shift.

Microphones.—Of several microphones available, the transverse current type has been used in majority of cases for direct sound pick-up.

Light Modulators.—Serious consideration was given to light modulators. Three were available, *i. e.*, mirror galvanometer, ribbon light-valve, and the gaseous discharge lamp. The latter was finally selected as being the most suitable in view of the requirements involved. As pictorial considerations were unnecessary, "toe" recording offered several advantages, the most attractive of which was that negative sound-track could be reproduced or re-recorded without the additional time and expense involved in making prints.

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received March 21, 1940.

** Canady Sound Appliance Co., Cleveland, Ohio.

A developing machine built on the premises permits maintaining the processing within close limits, and the toe-recorded track developed to a gamma of 2.00 has proved very satisfactory.

Preliminary tests made with gaseous discharge lamps available at the time indicated that before serious work could be undertaken, lamps with stable operating characteristics would have to be produced in sufficient quantities to permit

FIG. 1. Wave model drawn by a Morin harmonograph.

making replacements without investigating the idiosyncrasies of each lamp. Experimentation produced a lamp having the desired characteristics. The "current-light output" curve was linear over a wide range while the "time-current" curve showed little change over long periods of time. Frequency response and light output were satisfactory and phase-shift was not perceptible in the audio-frequency range.

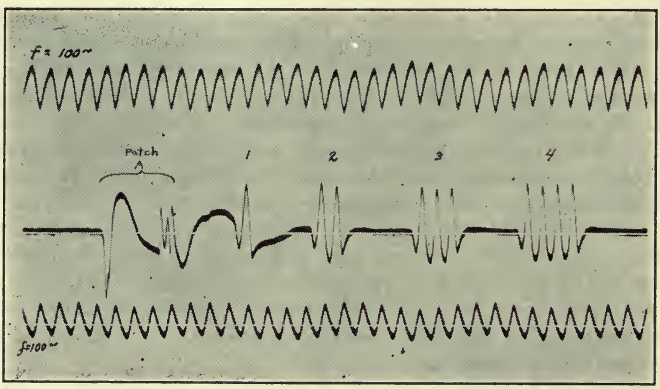

FIG. 2. Oscillogram of wave model of Fig. 1 after passing through three-stage transformer coupled amplifier.

Test Procedure.—Before the completed system was put into service, considerable time was spent in recording and reproducing complicated wave models. Wave models used for the tests were drawn by a Morin harmonograph, and the areas inked in with India ink. These were subsequently photographed on a reduced scale on film approximately 75 mm wide. After processing to a high gamma, the films were cleared to increase contrast between opaque and transparent areas.

The ends of the films were cemented together to form a small loop. In making the tests, the small film loops could be slipped onto a constant-speed drum and scanned similarly to the conventional methods except on a somewhat larger scale.

Fig. 1 shows a wave model containing one to four complete sine waves as drawn by a Morin harmonograph.

Fig. 2 is an oscillogram of the wave model shown in Fig. 1 after passing through the high-quality three-stage transformer-coupled amplifier. The disturbance at *A* was caused by a film patch.

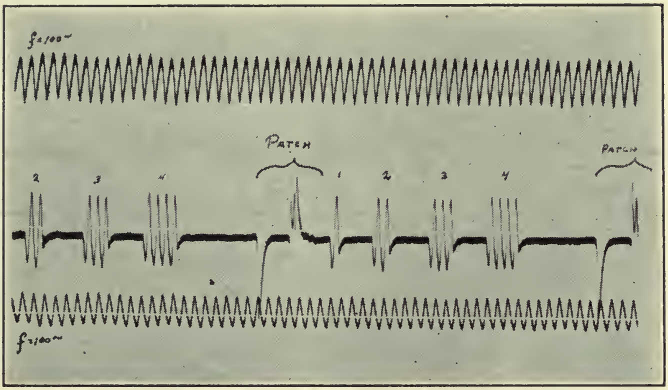

FIG. 3. Oscillogram after passing through a single 1:1 transformer coupled to the direct-coupled amplifier.

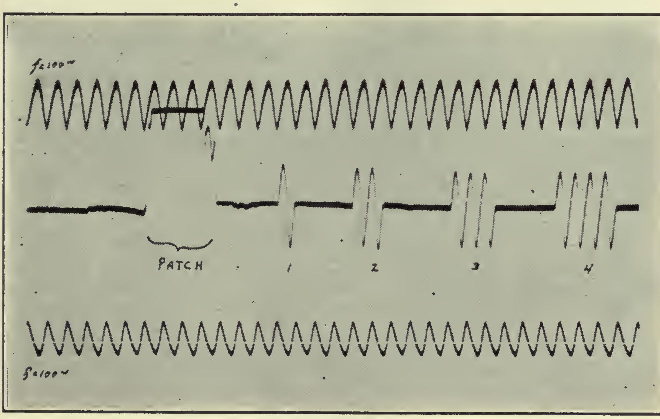

FIG. 4. Oscillogram after passing through direct-coupled amplifier.

Fig. 3 is an oscillogram of the wave model shown in Fig. 1 after passing through a single high-quality 1 : 1 audio-transformer coupled to the direct-coupled amplifier. The potential here is that of the d-c amplifier plus other distortions. (Note the overswing.)

Fig. 4 is an oscillogram of the wave model shown in Fig. 1 after passing through a direct-coupled amplifier. Note that the sine waves closely resemble those of Fig. 1, while the disturbance caused by the film patch is square-topped. Compare the base line with Figs. 2 and 3.

Fig. 5 is the overall characteristic of the complete system: at the top, the wave model input to the direct-coupled amplifier; at the bottom, the wave model after

FIG. 5. Overall characteristic of the complete system.

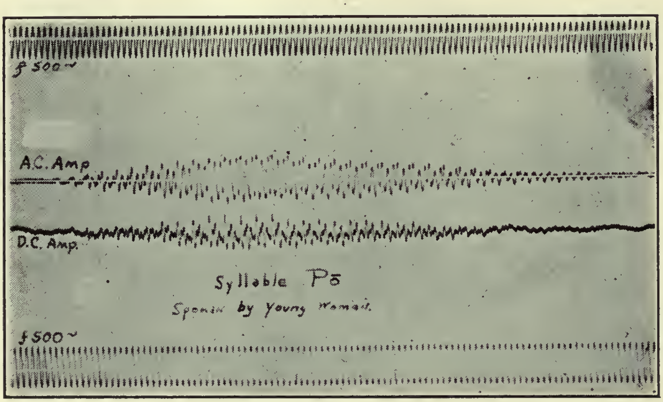

FIG. 6. Difference between direct-coupled and transformer-coupled amplifier; spoken syllable *po*.

going through the direct-coupled amplifier, gaseous discharge tube, *PJ-22* photocell, and preamplifier.

Figs. 6, 7, and 8 show the difference between a direct-coupled amplifier and a high-quality transformer-coupled amplifier. These are actual records showing speech syllables as amplified by each amplifier. The differences are relatively striking, and show the usual asymmetries encountered in a-c amplifiers as compared with d-c amplifiers.

Fig. 6 is an oscillogram of the speech syllable *po* as spoken by a young woman, using, at the top, a high-quality transformer-coupled amplifier, and at the bottom, a direct-coupled amplifier. Note the seeming regularity introduced by the a-c amplifier.

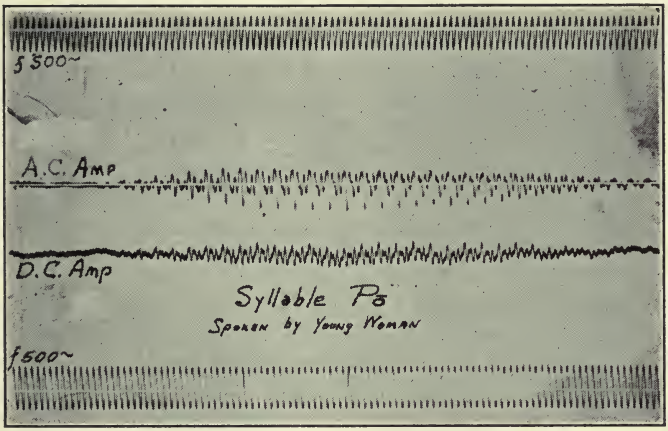

FIG. 7. Same as Fig. 6; spoken syllable *po*, by a different person.

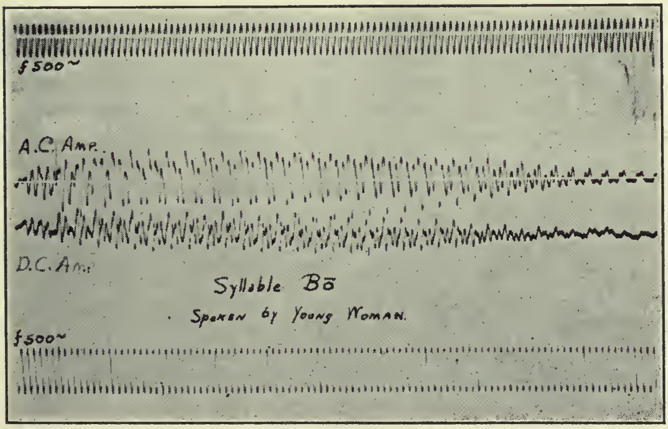

FIG. 8. Same as Fig. 6; spoken syllable *bo*.

Fig. 7 is the same as Fig. 6 except that the syllable *po* is spoken by a different young woman. This record is particularly good in showing the asymmetry of the peaks in the a-c amplifier.

Fig. 8 shows the syllable *bo* spoken by a young woman. In this record the peaks of the a-c amplifier are very great.

Conclusion.—As a matter of record, the two amplifiers used in the comparison tests gave identical qualities as judged by the ear. However, it is apparent that a Fourier analysis will give distinctly different results. It would be interesting to compare speech syllables after the second or third "dubbing" through a-c amplifiers with the same syllables amplified by direct-coupled amplifiers. In this case, the ear might detect a decided difference due to the accumulative asymmetries of a-c amplifiers.

Acknowledgment is made to Messrs. Brown and Snodgrass of Oberlin College for their coöperation in furnishing the oscillograms accompanying this paper.

REFERENCE

[1] CANADY, D., AND WELMAN, V. A.: "A Sound-Film Phonograph," *J. Soc. Mot. Pict. Eng.*, **XXX** (May, 1938), p. 591.

DISCUSSION

MR. WELMAN: This amplifier has been made available, and Mr. Canady is preparing to build it particularly for some universities who want specially high fidelity work, which the ordinary amplifier does not fulfil. It is being made in portable form.

MR. KELLOGG: In the listening tests were head-phones or loud speaker used?

MR. WELMAN: Both head-phones and loud speaker. The same microphone was used for both. The tests were made largely at the university, over a period of three years.

MR. ALBERSHEIM: What kind of microphone was used?

MR. WELMAN: The microphone was made by Telefunken, model *ELA M46*. This microphone was developed by Reisz and has been manufactured by various concerns in Europe. It is known as a "transverse current microphone" because a current passes transversely across the microphone and parallel to a silken diaphragm. The latter forms the front wall of a receptacle filled with carbon granules. Current traveling transversely across the microphone is modulated by the variation in pressure of the carbon granules caused by the vibration of the diaphragm.

The microphone has a relatively high impedance, and faithfully handles frequencies up to 10,000 cycles. It was chosen primarily because it could be connected to the grid of the input tube without the use of a coupling transformer. The output is higher than that of the conventional carbon-button type and the hiss level is considerably lower.

MR. SEELEY: What is the upper frequency limit of resolution of the optical system used in recording these waves?

MR. WELMAN: The upper frequency limit was originally set at 10,000 cycles; 11,000 cycles has recently been recorded. It should be borne in mind that no printing losses are involved as the negative track is reproduced.

In the listening tests, head-phones and loud speakers seem to be the "bottle neck" of the system.

PROFESSIONAL 16-MM RECORDING EQUIPMENT*

D. CANADY**

Direct variable-density recording is rapidly gaining favor in the 16-mm field. This is to be expected as good 16-mm variable-density recorded track with noise reduction compares favorable with 35-mm track made by commercial motion picture producers. Hollywood technicians are overwhelmingly in favor of the variable-density method and there is little doubt that 16-mm film producers will soon adopt directly variable-density recording as standard practice.

Professional Type 16-mm Sound-on-Film Recorder.—The professional type 16-mm film recorder described here has been designed and built to meet the requirements of the commercial producer of 16-mm films. The complete machine is shown in Fig. 1. Constant film-speed is assured by a rotary stabilizer of the dry type, which is not affected by climatic conditions. All shafts rotate on ball bearings. The recording-drum shaft and recording-drum pad-roller revolve on precision ball-bearings selected for their smooth running qualities. Provision has been made for lateral adjustment of guide flanges and pad-roller pressure is adjustable over a wide range.

A gaseous discharge lamp is used as a light-modulator, and the output is focused on the film by an optical unit of high resolving power. Microscopic examination of frequency runs 30 to 10,000 cps recorded on standard recording emulsion show clean-cut striations up to 9000 cps. As no commercial 16-mm sound projector is capable of reproducing frequencies of this order, the recorder should meet all requirements of 16-mm producers for some time to come.

Faithful recording of high audio frequencies is necessary for good sound quality. Careful and precise adjustment of the optical systems in 16-mm recorders is of the utmost importance. Because of the restricted area available on 16-mm film, there is a definite limit to the number of striations that can be photographed per second.

Under present standards, optimal results can be achieved by using a very narrow slit sharply focused on the film. While optical units can be sharply focused and sealed at the factory, this practice does not permit adjustments being made for tolerances encountered in film stock. Furthermore, a slit image sharply focused on film tightly wrapped around a stationary drum will not necessarily remain in optimal focus when the film is in motion. In film recorders using film-driven, free-running recording drums mounted on ball-bearings, the distance between the optical unit and the emulsion surface is subject to slight variation due to (*1*) types and makes of film stock and (*2*) degree of film flexibility. Film stock varies in thickness according to type and manufacturer. The flex of a film loop changes with respect to age and moisture content of the emulsion. Fresh stock is usually pliable and adheres closely to the surface of the recording drum while old or driedout film is less resilient and has a tendency to "bulge" away from the drum. (Fig. 2.)

*Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 15, 1940.

** Canady Sound Appliance Co., Cleveland, Ohio.

Because high frequencies are completely lost when the distance between the optical unit and emulsion surface vary slightly, the optical system of the professional 16-mm recorder has been provided with a micrometer focusing adjustment. Accurately cut detents closely spaced around the periphery of the focusing ring make extremely accurate focusing possible. Optimal focus for any particular recording stock can be effected quickly by following simple directions furnished with each machine. External means are provided for azimuth adjustment of recording slit.

Sound-track Optical Reduction Printer.—The sound-track optical reduction printer here described has been improved by the addition of a special optical unit. In conventional optical reduction printers the optical system is quite critical, and any irregularities of speed between the two films causes distortion of sound

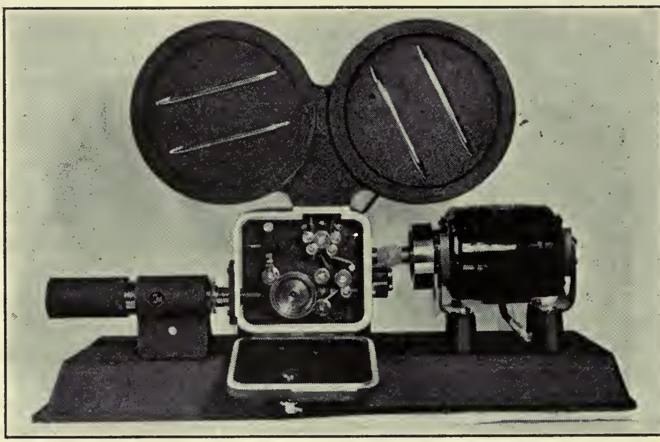

FIG. 1. Professional type 16-mm sound-on-film recorder.

quality. Modern practice requires that the reduced track be an exact duplicate of the 35-mm negative; that is, if the negative is of the variable-density type, the 16-mm track will be variable-density. If the negative is variable-area, the reduced track will be variable-area.

With the new optical unit, the reduced 16-mm track will be of the variable-density type regardless of the type of sound-track on the 35-mm negative. No direct optical relation exists between 35-mm track and the reduced 16-mm track. Distortion caused by shrinkage of the 35-mm track is reduced to a minimum.

While satisfactory results have been obtained using standard exciting lamps, the high-pressure mercury-vapor lamp will be furnished as standard equipment unless otherwise specified. Optical printers can be furnished with the new optical unit to print 35-mm to 35-mm sound-track as well as 16-mm to 16-mm. Sixteen-mm prints made from 16-mm sound-track negative by optical printing are decidedly more "brilliant" than those made by contact printing. This is due to less slippage and increased contrast brought about by projection printing.

Noise-reduction Unit for Mercury-vapor High-pressure Lamps.—The noise-reduction unit described in the May, 1939, issue of the JOURNAL[1] has been increased in size to provide noise reduction to high-pressure mercury-vapor lamps now used as light-sources in certain recording apparatus. Electronic in operation, the noise-reduction unit permits high-speed operation to prevent speech clipping. By applying noise reduction to the mercury-vapor lamp, danger of ribbon clash is entirely eliminated. With certain modifications to existing recording equipment, the 85-watt high-pressure mercury lamp can be used to replace conventional

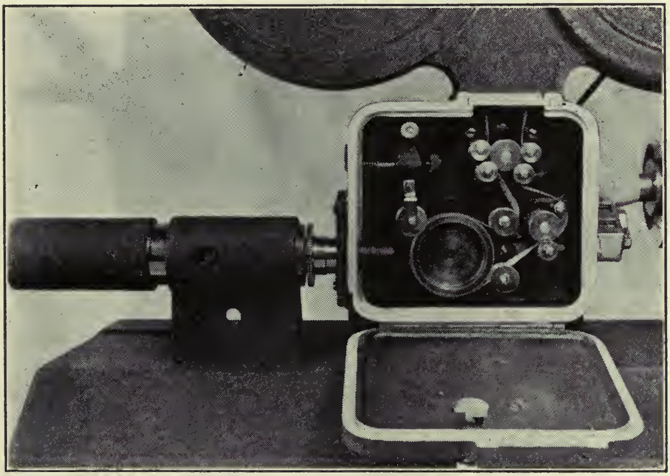

FIG. 2. Close-up of the mechanism.

glow-lamps. While no tests have been made to determine the amount of phase-shift present, test recordings as judged by the ear to indicate there is a definite dropping off at high frequencies. This discrimination can, of course, be overcome by a compensating network in the amplifier circuit.

REFERENCE

[1] CANADY, D. R., AND WELMAN, V. A.: "New Sound Recording Equipment," *J. Soc. Mot. Pict. Eng.*, **XXXII** (May, 1939), p. 544.

DISCUSSION

MR. KELLOGG: In your second illustration, the film appeared to pass from under the drum around another roller. I could not see whether the latter was a sprocket or not.

MR. WELMAN: It is a sprocket with an aperiodic dampening filter on it.

MR. KELLOGG: Does the printer use a similar system?

MR. WELMAN: Yes. The optical reduction printer consists of two independent rotary stabilizers connected to film-driven drums. The sprockets, take-ups, *etc.*, are driven by a constant-speed motor.

MR. THOMPSON: The statement was made that the recorder is focused to the

difference in thickness of various types of film from time to time. If that is the case, then when you start recording, how do you know whether the film is the right thickness or not, and how do you focus for it? Would you have to focus the recorder for every roll of film? If that were the case, it seems to me that the results would be inconsistent.

MR. WELMAN: Our experience has been that Agfa film, for instance, is not the same thickness as Eastman film, and a few thousandths or parts of thousandths of an inch difference in the focusing makes a great difference in the sound. In the work we have done each lot of film that is used has had a sample focused at the beginning.

DR. CARVER: How much do you actually have to move the focusing device? Is it a matter of a tenth of a thousandth?

MR. WELMAN: The optical unit moves 0.00038″ per step. With the unit sharply focused, a variation of three steps plus or minus is noticeable when test frequencies of 6000 to 8000 cycles are being recorded.

MR. OFFENHAUSER: That seems to be contrary to our experience as manufacturers of 16-mm sound-recording equipment. It has been our policy and practice to ship out 16-mm sound-recorders with the hope that our customers will not touch them. It has been our experience, too, that the whole question seems to be tied up with the design of the mechanism and optics of the recorder. If the mechanism is properly designed, the extremely small variations in the thickness of the film and of the film emulsion, as we normally meet them, are decidedly minor matters. Practically speaking, for something like three years we have had equipment on the market, and to the best of our knowledge and belief there has not been a single instance where a readjustment of focus of the equipment has been required in any one of the equipments in use.

MR. WELMAN: On the other hand, you do not know that a readjustment might not have done better recording.

MR. OFFENHAUSER: We periodically check equipment brought in to us by customers in the average period of a year. At the end of a yearly interval, it has not been found either desirable or necessary to alter the focus, not even as much as one five-thousandth of an inch. We put in our file the original test records, and then compare the original test records with those made when the machine comes in for repair and inspection. Ordinarily, in the case of domestic equipment, that occurs about once a year, and the difference between the two records usually shows an improvement in favor of the later-made film, on account of the fact that there have continually been improvements in the film stocks in the interim. The film manufacturers have not been telling us about it, but we do find that gradual improvement has been occuring almost with steady regularity. If anything, we find an improvement in operation after equipment has been in use and such improvement, of course, we obviously can not attribute to improvement in the machine itself, but rather in the film and its processing. The variation in film thickness and emulsion thickness seems to us to be of negligible importance.

MR. KELLOGG: I have seen some samples, particularly of 16-mm film, that had such a tendency to curl that even when wrapped around a small drum, they still assume something of a trough-shaped form, or curl up at the edges. In a bad case of that kind, I think it might affect the focus. What experience has any of you had with such films?

MR. MAURER: In Mr. Canady's recorder, if I understand correctly, is a film-driven drum, and the film is relatively at little tension as it goes around the recording drum. In the recorder to which Mr. Offenhauser is referring, the film is under considerable tension as it goes around the recording drum, and the recording drum is a solid surface which supports the film fully at all points across the width of the film. In our observation, we have run across only one piece of stock that was as much as half a thousandth of an inch different in thickness from the stock regularly supplied, and that was a piece of stock of foreign manufacture. In the optical system as employed, a difference of a half a thousandth in the focus would not produce a difference of as much as one decibel in the response at six thousand cycles.

MR. CANADY:* We are a little concerned over the variation of film stock manufactured in the United States. When recording equipment is shipped to foreign countries due consideration must be taken of the fact that the customer may be compelled to use film stock of local manufacture. Some countries will not permit the importation of raw stock, and in many cases the local product differs in thickness and width from the American product.

Of course, it is a simple matter to furnish an optical system that would not be affected by variations in film thickness, but it would not have high resolving power. Good quality demands that the high frequencies be faithfully recorded. In the 16-mm field this can be done by using a carefully designed optical system. Lenses with high resolving power require precision adjustment facilities. Such a lens is either in focus or it is not. There is no "zone" where a slight variation either way is permissible without impairing the sharpness of the image.

With a well designed focusing device, an optical system of high resolving power is easily focused for the variations among different brands of film stock, and permits the equipment to work at maximum efficiency.

In transit, whether over several thousand miles or across town, recording equipment is often subjected to rough handling. No matter how carefully packed or well built, severe shocks can throw the best optical systems out of adjustment, and focusing facilities for the optical system will prove invaluable.

Where optical systems are focused and sealed at the factory, and if adjustments are attempted locally without proper equipment, the results may be anything but satisfactory.

When equipment is sent to the factory for adjustment, the owner is deprived of the use of the equipment. In some instances the time lost will be at least two to three months. In addition to the shipping expense involved the owner would not be sure that the equipment was in perfect condition when it was returned. Anyone who has witnessed shipping cases rolling around in the hold of a ship in heavy seas will understand what I mean.

From the manufacturing standpoint, optical systems focused and sealed at the factory are cheaper to build. Where the interests of the customer are considered, the additional expense involved in the manufacture of a micrometer focusing device is a minor factor indeed.

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* Communicated.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

American Cinematographer

21 (July, 1940), No. 7

Surveying Major Studio Light Levels (pp. 294–296, 334) — W. Stull

Making a 16-Mm Middleweight Camera Dolly (pp. 310–311) — H. Hunt

Effect of Aeration on Photographic Properties of Developers, II (pp. 319–321) — J. I. Crabtree and C. H. Schwingel

Putting Scene Slate into Camera (pp. 322–323) — W. Stull

Hollywood Hears Stereophonic Reproduction . . . It Is Good (pp. 325–326)

British Journal of Photography

87 (June 21, 1940), No. 4181

Progress in Color (pp. 301–302)

Communications

20 (June, 1940), No. 6

Television in Natural Color (pp. 8, 27–28)

Educational Screen

29 (June, 1940), No. 6

Motion Pictures—Not for Theaters, Pt. 18 (pp. 235–238, 242) — A. E. Krows

Electronics and Television and Short-Wave World

13 (June, 1940), No. 148

Volume Range of Sound-on-Film Recording (pp. 245–249) — R. H. Cricks

Recent Progress in Television Studio Technique (pp. 275–276, 288–289)

Institute of Radio Engineers

28 (May, 1940), No. 5

A System of Large-Screen Television Reception Based on Certain Electron Phenomena in Crystals (pp. 203–212) — A. H. ROSENTHAL

International Photographer

12 (July, 1940), No. 6

Theory of Three-Color Photography, Pt. II (pp. 7–12) — K. MARCUS

Kinotechnik

22 (April, 1940), No. 4

Ueberblick über den Stand des Problems: Vergleich zwischen Zacken-und Sprossenschrift (Glance at the Present Position of the Problem: Comparison between Variable Width and Variable Density) (pp. 45–51) — M. ULNER

Die Anforderungen an einen zuverlassigen Belichtungsmesser (Requirements for an Accurate Exposure meter) (pp. 51–54) — E. RUST

Verwendungsmoglichkeiten von Altfilm aus Azetylzellulose (Possibilities for Using Old Cellulose Acetate Film) (pp. 54–55) — E. RADLOFF

Motion Picture Herald

139 (June 29, 1940), No. 13

Hollywood Considers 3-Dimensional Sound (p. 18)

Motion Picture Herald (Better Theaters Section)

139 (June 29, 1940), No. 13

Taking Advantage of the Advancement in Accessories (pp. 31–32, 34) — J. J. SEFING

Simplification and Convenience Mark Design of New Projector (pp. 34–35)

The A. C. Arc as a Source of White Projection Light (p. 36)

Photographische Industrie

38 (May 22, 1940), No. 21

Das Petzval-Voigtlander-Objektiv und seine Fortentwicklung als Projektions-System. III (Further Development of the Petzval-Voigtlander Lens in the Projection System) (pp. 324–326) — K. PRITSCHOW

Physical Society Proceedings

Sound-Absorbing Properties of Some Common Out-Door Materials (pp. 371–379) — G. W. C. KAYE AND E. J. EVANS

1940 FALL CONVENTION

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Headquarters

Headquarters of the Convention will be the Hollywood Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Daily hotel rates to SMPE delegates will be as follows (European Plan):

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00–14.00
Parlor suite and bath, 2 persons	12.00–16.00

Room reservation cards will be mailed to the membership early in September, and should be returned to the Hotel immediately to be assured of satisfactory accommodations.

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	*Railroad Fare (round trip)*	*Pullman (one way)*
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	135.00	23.65
Detroit	106.75	19.20
New York	135.00	22.85
Rochester	124.05	20.50
Cleveland	111.00	19.20
Philadelphia	135.00	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips. Arrangements may be made with the railroads to take different routes going and coming, if so desired,

but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems. Technical sessions will be held in the *Blossom Room* of the Hotel. Several evening meetings will be arranged to permit attendance and participation by those whose work will not permit them to be free at other times. The Local Papers Committee is collaborating closely with the General Papers Committee in arranging the details of the program.

Studio Visits

The Local Arrangements Committee is planning visits to several studios during the Convention week. Details will be announced in the next issue of the JOURNAL. Admittance to the studios will be by registration card or Convention badge only.

New Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore Rooms* of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the General Office of the Society at the Hotel Pennsylvania, New York, N. Y.

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, October 23rd, in the *Blossom Room.* A feature of the evening will be the annual presentations of the SMPE Progress Medal and the SMPE Journal Award. Officers-elect for 1941 will be announced and introduced, and brief addresses will be delivered by prominent members of the motion picture industry. The evening will conclude with entertainment and dancing.

The Informal Get-Together Luncheon will be held in the *Florentine Room* of the Hotel on Monday, October 21st, at 12:30 P. M.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. L. L. Ryder, *hostess*, and the Ladies' Committee. A suite

will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; Beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the West, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

Those who wish to visit San Francisco may arrange for stop-over privileges when purchasing their railroad tickets. Arrangements have been made with the Hotel Mark Hopkins for single accommodations for $5 daily and double with twin beds for $7, both with baths. The Fairmont Hotel also extends a rate of $4 single and $6 double, with bath. Reservations may be made by writing directly to the Hotel.

W. C. KUNZMANN,
Convention Vice-President

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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TELEVISION PICK-UP OF THE PASADENA ROSE TOURNAMENT PARADE *

JANUARY 1, 1940

HARRY R. LUBCKE**

Summary.—*The first television pick-up of the Pasadena Rose Tournament Parade was made on New Year's Day, 1940. This was accomplished with the "suitcase" type portable television equipment and beam transmitter* W6XDU *of the Don Lee Broadcasting System.*

Two television cameras were used to give long-shot and close-up views of the floats, the cameras being arranged to give instantaneous switching of scene. The distance from Pasadena to the Don Lee Building, site of the home transmitter W6XAO, *is nine miles and the line of sight was interrupted by two hills and buildings. Since the portable transmitter operates on a wavelength of less than one meter, much effort was therefore directed toward erecting high and efficient antennas at the transmitter and receiver.*

Diathermy machines, as used by the medical profession, were found to cause interference even on the beam transmitter frequency of 324 megacycles, indicating the need for proper shielding of such devices.

The sound portion of the broadcast was sent over the nationwide Mutual Network. Camera work and aural description were adequately synchronized. Although rain fell during the parade and the morning was darkly overcast, written statements of reception from W6XAO *lookers up to 15 miles away reported clear images, enabling them to read the names on the floats and discern other items of detail.*

This paper is concerned with televising the Pasadena Tournament of Rose Parade for the first time, on January 1, 1940, by means of new portable television pick-up equipment of the Don Lee Broadcasting System.

Prior to the tests over a nine-mile path for the parade pick-up, successful operation had been obtained over 2.3 miles. This was from the Don Lee Salon on Wilshire Boulevard at Kingsley to the Don Lee Building at Seventh and Bixel Streets. In these tests a hayrake antenna, as shown in Fig. 1, was used at the transmitter, and a double-*V* antenna, as shown in Fig. 2, was used at the receiver.

---

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 15, 1940.

** Don Lee Broadcasting System, Los Angeles, Calif.

The hayrake antenna consists essentially of a folded half-wave dipole fed with a 375-ohm 2-inch spaced feeder and mounted in a *V* reflector consisting of two groups of $^3/_4$-wavelength-long copper tubes separated at an angle of 45 degrees. The double-*V* antenna consists of four half-wave *V* groups separated one-half wave vertically and backed one-fourth wavelength behind by an identical group of reflectors.

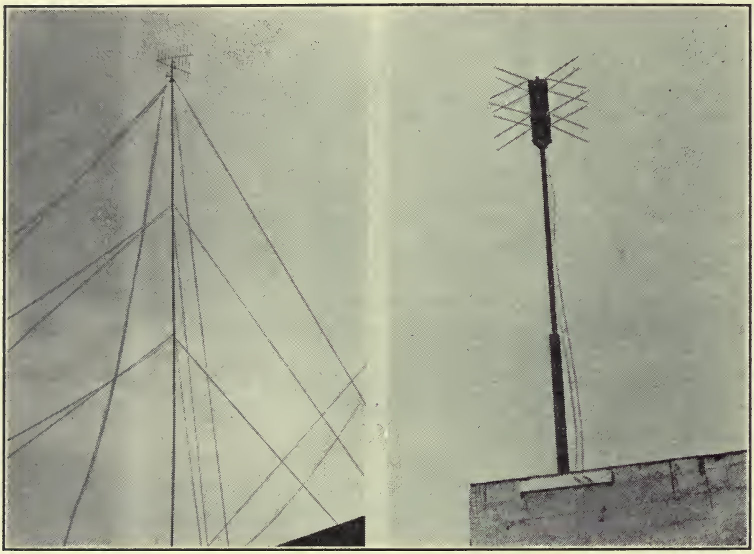

FIG. 1. (*Left*) Modified hayrake antenna as installed on a 43-foot duralumin mast at Elks' Club, Pasadena. Mast capable of rotation to orient antenna.

FIG. 2. (*Right*) Double-*V* antenna and reflector used in 2.3-mile tests and first Pasadena tests. Elevation 18 ft above the roof of a 100-ft building.

With this equipment interference-free images were received, and retransmitted over regular television broadcasting station *W6XAO* operating on channel 1 (44 to 50 megacycles). The waves were required to pass through or around the Ambassador Hotel. This was located about one-third the distance from the transmitter to the receiver, and surmounted the line of sight by approximately 30 feet.

When the identical equipment and antenna were installed and operated over the Pasadena Parade path, the signal was very weak. The profile of the transmission path gradually fell from Pasadena to

Los Angeles with two small hills in the line of sight about three miles from the latter location (Fig. 3).

The *W6XDU* transmitter consists of a $6^1/_4$-watt RMA television carrier, crystal-controlled unit rated at 324 megacycles. Two camera

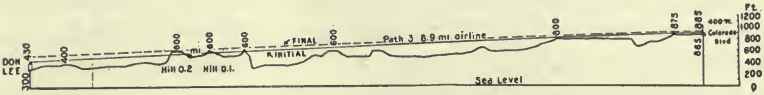

FIG. 3. Profile of transmission path from Pasadena to Los Angeles.

chains, master control, and synchronizing equipment comprise the video units. The receiver is a 324-megacycle superheterodyne with an intermediate frequency pass-band of 17.5 to 29.5 megacycles. This equipment was manufactured by the Radio Corporation of

FIG. 4. Elks' Club, Colorado Blvd. near Orange Grove Ave., Pasadena. Transmitting antenna is seen to the right of the flagpole.

America, and was the first set of the "suitcase" type that was constructed.

The transmitting location for the Pasadena tests was the Elks' Club building on Colorado Blvd., near Orange Grove Ave. It is shown in

Fig. 4. This site was selected because it was in the first portion of the line of march, it gave a good elevation for cameras, close proximity to the antenna, and an absence of tall buildings which would shade the street from the sun.

Antenna Tests.—Fig. 4 shows the transmitting antenna at its ultimate height located just to the right of the flagpole. A close-up of the installation is shown in Fig. 1. A $1^1/_2$-inch duralumin mast 43 feet high is shown. In the first tests this mast was only 12 feet high. In this position and with the transmitter in the open on the balcony as shown in Fig. 5 a number of transmitting antenna tests were made.

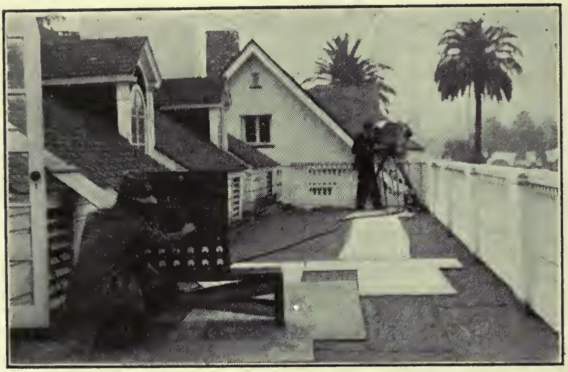

FIG. 5. Portable television transmitter *W6XDU* and one RCA camera as installed on third floor balcony of Elks' Club for parade telecast.

Several tests were made with the folded dipole in the hayrake reflector array. It appeared to be difficult to feed the antenna properly and to cause the high-impedance point to occur at the theoretical position. Serious standing waves existed on the feeder in spite of numerous adjustments. The junction of the feeder matching section and the folded ends of the dipole was consistently the high-impedance point, with the physical extremities of the dipole a low-impedance point, contrary to theory. The length of the folded dipole was altered considerably, with no change in the results. Equally good results over the transmission path were achieved by utilizing only the folded portions of the dipole as a half-wave antenna of insufficient length. The next step was to employ an ordinary half-wave antenna in the hayrake reflector 17.2 inches long delta-fed by spreading

the 2-inch-spaced feeders a distance of $7^1/_2$ inches at the point where they fastened to the antenna. With this antenna "grounded" at the center to the hayrake reflector the latter was "hot" with current. The transmission results were inferior to the original arrangement.

The final arrangement consisted of the above half-wave antenna, delta-fed but insulated from the hayrake reflector. This arrangement gave signals of slightly greater strength than the original folded dipole, an absence of standing waves on the feeders, and satisfactory loading conditions on the transmitter.

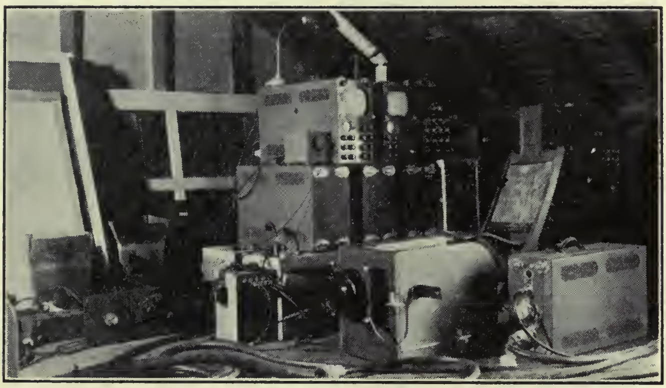

FIG. 5(*a*). Video equipment inside Elks' Club. Two camera monitors and master control monitor on top row; synchronizing equipment on bottom row. (Camera and auxiliary unit in foreground.)

Rotating the transmitting antenna indicated that it was not emitting a sharply directional beam. Departure of 30 degrees either side of the line of sight to the receiver had little effect upon the received signal strength. Subsequent tests proved that being off line of sight contributed to this behavior. In contrast, the double-*V* receiving antenna gave a sharp maximum signal within ± 5 degrees of the line of sight.

The first step toward improving the signal-to-noise ratio was the erection of a 15-wavelength *V* antenna. The central angle was 25 degrees. The extremity of each wire of the *V*, which was approximately 45 feet long, was terminated in a two-turn $^1/_2$-inch diameter coil, a 400-ohm non-inductive resistor, and half-wave rod 18 inches long mounted vertically. Victron insulation was used for feeder

spacers and other insulation points. All the tests made to date have been with horizontal polarization. The vertical half-waves on the *V* antenna thus intercepted a minimum of energy and acted as efficient "grounds."

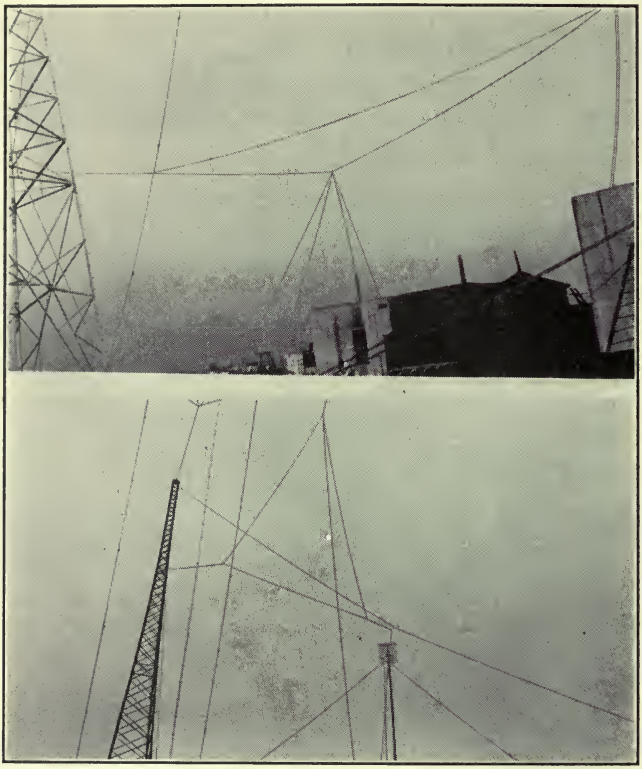

FIG. 6. (*Upper*) Twenty-wavelength *V* antenna. Free ends at center, feeder at right. Elevation 33 ft above the roof of a 100-ft building.

FIG. 7. (*Lower*) Hayrake receiving antenna, lower center. Elevation 51 ft above the roof of 100-ft building. Twenty-wavelength *V* antenna upper center. Elevation 100 ft above 100-ft building.

This antenna was 15 feet higher than the former double-*V* receiving antenna of Fig. 2, mounting to 33 feet above the top of a 100-foot building. The antenna was supported at three points by ropes, as shown in Fig. 6. By means of pulleys the antenna could be steered to the necessary line of sight.

This antenna gave a considerably stronger signal than the double-*V*. It was quite directional. With the original angle of 25 degrees, maximum signal was obtained when the west wire of the *V* was allowed to sag about 10 feet lower than the east wire. The next step was to vary the angle of the *V*. Decreasing the angle definitely reduced the signal. The next operation was to increase the length of the antenna to 20 wavelengths by adding 14.3 feet to each wire. This effectively narrowed the angle and no signal increase was noted. The opening of the *V* at this time was 13 feet. Increasing this opening 6 feet to 19 feet gave twice the former signal. At this point moving automobiles and bleachers along Colorado Boulevard were discernible. Increasing the width of the *V* by 3 feet more gave a further increase in signal and required that the west and east wires be at the same height to obtain maximum pick-up. This indicated that the former slack position of the west wire was an artifice that effectively increased the angle of the *V*.

The next operation was to change the lengths of the wires of the *V*. By removing 3 inches from both wires the signal again doubled. The final length of each wire of the *V* antenna was 57 feet and the separation at the wide end 30 feet, which corresponds to an angle of 31 degrees. It was interesting to note that the best results were attained with such a small change of length as 3 inches in 57 feet, and that the angle was considerably greater than the theoretical value of 25 degrees. The directivity of the antenna was definite.

Although this antenna gave reasonably good images it was decided to test it against a hayrake receiving antenna. This was composed of a prescribed hayrake assembly, as described above, with a folded dipole shortened to 18 inches total length, as former transmitting tests had indicated as optimal. This installation is shown in the lower central part of Fig. 7. This was mounted at an increased height of 18 feet over the former *V*, or a total of 51 feet above the roof of the 100-foot building. A pivot arrangement was provided at the top of the wooden mast so that the direction of the antenna could be changed. These ropes are shown in Fig. 7. In spite of the greater height the signal was approximately the same as with the former *V* antenna. Orienting the antenna did not change the signal strength appreciably.

At this point the transmitting antenna was raised by another section of duralumin mast, increasing the height from 12 to 24 feet above the building of Fig. 4, which is approximately 50 feet high.

This doubled the received signal strength. The considerable signal increase from the small increment in height was caused by raising the line of sight just above certain trees and frame residences about one mile from the transmitter. The two hills still intervened, however.

The final reception antenna change consisted in increasing the height of the formerly adjusted *V* antenna to 100 feet off the roof, making it 200 feet off the ground. This is shown in the upper part of Fig. 7, with the open ends of the *V* near the tower and "skyrope," respectively, and the top end of the feeder at the top edge of the photo. This change increased the signal strength three more times.

The final antenna change was made at the transmitter, where somewhat more than $1^1/_2$ sections of duralumin mast were added, building the total height to 43 feet, as shown in Fig. 4. This again doubled the received signal strength. With these increased heights the profile along the line of sight was definitely raised but the results were such as to indicate substantial obstacles still in the path, at least a few buildings.

To summarize, it can be said that a *V* antenna proved the most satisfactory as regards gain and directivity, that the hayrake antenna was less satisfactory, and that the double-*V* antenna was comparatively satisfactory. In all cases, the additional loss of feeder at the receiver and at the transmitter had no effect compared to the increased signal resulting from the additional height. In this one path at least, the height of the receiving and transmitting antennas was the most important factor in obtaining adequate signal strength.

Incidentally, it was found that the television cameras could be located as close as ten feet from the transmitter and feeder to the antenna without radio frequency feedback. The antenna was 40 feet away airline, higher, and pointing away from the cameras.

Interference.—The most apparent interference was the thermonic noise of the intermediate frequency stages of the television beam receiver. Fundamental research on reducing this noise would have a definite effect upon increasing the maximum range of the portable equipment.

Surprisingly, diathermy medical machine interference was experienced on the ultra-high-frequency of 324 megacycles. It was tunable by adjusting the oscillator frequency of the receiver. This indicates that the energy received was approximately at 324 megacycles, and not in the 17.5 to 29.5 intermediate-frequency band of the re-

ceiver. It was also found that diathermy interference could be neutralized in certain instances by carefully orienting the *V* antenna. The effect of diathermy interference was great on the nine-mile Pasadena pick-up. On the 2.3-mile test diathermy herringbone patterns had been noted. These were undoubtedly the same machines, but of less effect because of the greater signal strength. Many personal and telephone calls to suspected locations did not locate the sources. Further tests by the diathermy-locating automobile of the Television Service Engineers of Los Angeles also could not locate the sources. The diathermies usually had a fundamental of about 25 megacycles, and simultaneously interfered with 45.25-megacycle television reception in the Don Lee Building.

Another serious interference in this particular installation was the 900-kc radio-frequency energy of radio broadcasting station *KHJ*. At the maximum, with the 100-foot *V* antenna, $^1/_3$ ampere of radio-frequency current flowed in the *V* feeders. This was reduced to a considerably smaller value by placing 150-$\mu\mu f$ mica condensers in each feeder at the receiver. The feeder length was also adjusted by a few inches to give maximum signal-to-noise ratio. The condensers had a "quarter-wave effect" of nine inches effective length as would be expected.

A quarter-wave "short" to all frequencies other than 324 megacycles was also utilized. This was composed of a 9-inch length of wire from each feeder at the receiver terminals to ground. Tests indicated that this had no effect upon the received signal strength but served to remove residual pick-up of television station *W6XAO* in the beam receiver.

This short did not have appreciable effect upon *KHJ* interference. The ground configuration at the receiver had a large effect upon the *KHJ* pick-up. The best ground was obtained by running a No. 12 wire to the iron ladder shown in the rear of Fig. 8. A change of a few inches in the length of this lead would greatly alter the amount of *KHJ* interference.

A further manifestation of *KHJ* interference was inherent in the video line of approximately 125 feet from television beam receiver to *W6XAO* transmitter. It was necessary to locate the beam receiver at this distance from the transmitter in order to avoid feedback at the high gain setting necessary in this nine-mile pick-up. The receiver is shown in Fig. 8 as installed in an elevator penthouse on the Don Lee Building.

Four different video line configurations were installed. The first was a copper-braid shielded rubber-insulated 72-ohm coaxial conductor, which was run beneath a 1-inch conduit on the ceiling of the eighth floor of the Don Lee Building. The sheath was insulated from all objects, and by grounding at the transmitter end a minimum of pick-up resulted.

A second line on the ceiling of the seventh floor of the Don Lee Building was considerably inferior to the above line. It was expected that the reverse would be true because the *KHJ* and *W6XAO* transmitters are located on the eighth floor with the antennas on the roof.

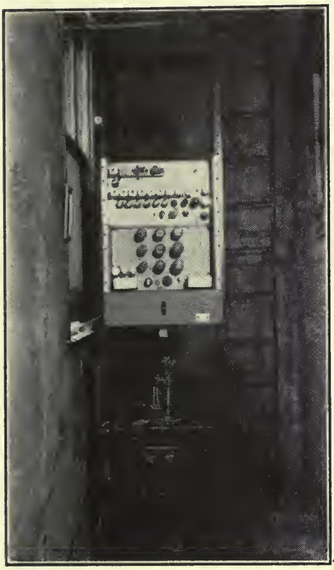

FIG. 8. Beam receiver, 324 mcs as installed on roof of Don Lee Building for parade telecast.

The third line consisted of the same sheathed coaxial line lying on the roof. The fourth line, also on the roof, was composed of $^3/_4$-inch thin-walled conduit with fabric loom inside, with the above coaxial cable pulled through it. This gave double insulated shielding throughout the length of the run. The receiver end can be noted coming into the window at the left of Fig. 8. In the final arrangement the conduit was not grounded at any point, but the outer sheath of the coaxial conductor was grounded at both ends of the run.

A further type of interference was caused by the sparking of heavy elevator controls in the same building with the beam receiver. These contacts broke between 200 and 500 amperes. The most important effect on the signal was a 200 per cent change of the d-c level. The current broken was d-c; the receiver was operated on a separate single-phase a-c line. This was eliminated during the parade by not operating the elevator.

Parade Conditions.—A normal winter-light intensity for Los Angeles is from 250 to 650 on a Weston brightness photometer of the usual type (measuring brightness in foot-candles per square-foot). Tests with the portable pick-up equipment had shown that lighting of 80 was necessary to give a good image.

The morning of the parade was very dark and overcast, giving a reading throughout of 40. The parade started promptly at 9:15 A. M. and concluded at 11:00 A. M. During the last half of the parade it was raining, from medium to light intensity. At home receivers seven miles from *W6XAO* it was possible to see the wet streets at certain camera angles before the announcer admitted it was raining. In Figs. 9 and 10 the papers on the heads of the spectators and the covers on the equipment indicate the conditions.

Because the day of the parade was a holiday the background interference over the relay link was approximately half that of a normal working day. This fact, combined with operation at maximum camera sensitivity and continued attention to shading adjustments, made the picture satisfactory. In Fig. 9., for instance, on home receivers it was *not* difficult to see the girl on the front of the bell of the float shown. The bell rocked back and forth. The contrast between the bell and the girl was small, as can be noted in the photograph. It was possible to read the names on all the floats save one, as reports as far as fourteen miles from transmitter *W6XAO* so stated.

Operative Set-Up.—The televising of the parade was done in conjunction with the aural broadcast sent over the nationwide Mutual network. There existed a dual problem in synchronizing camera operations with word description of the event and the proper aural presentation for a nationwide audience. Two motion picture trained television cameramen, McEdwards and Warren, operated the cameras. One camera had a $6^1/_2$-inch $f/3.5$ lens and the other a 19-inch $f/4$ telephoto lens. The camera pick-ups were viewed and shaded by television engineers Pitzer and Jury. The former also monitored the transmitter *W6XDU* adjustments and the latter switched cameras at the master control unit. He was provided with double headphones, one of which gave out instructions and the other the network sound output. A breast-type telephone transmitted his instructions to the cameramen. There was also a television production supervisor, Sawyer, assistant, Waldegrave, two announcers, Albright and Young, two sound engineers, Kennedy and Murray, and a radio production supervisor, Van Newkirk.

The point of greatest nervous intensity was at the master control unit. The network announcers were allowed to describe the parade as they saw it, with general instructions as to the tempo of their description. It was necessary to have their description of a particular float end as the float reached the limit of the camera panning range.

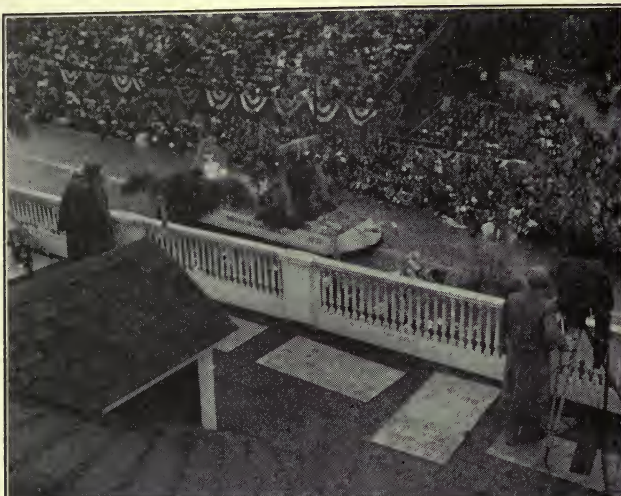

FIG. 9. (*Upper*) Parade scene. San Gabriel float. Cameraman McEdwards right, producer Waldegrave left.

FIG. 10. (*Lower*) Parade scene. Note wet streets and papers over heads of spectators in grandstands. Aural broadcast personnel at right foreground.

The usual technic was to establish the existence of a float and surroundings by the wide-angle $6^1/_2$-inch lens, and then to follow it from an advance position to a point somewhat beyond the location of the camera with the 19-inch lens. During this time the announcer gave the description and interesting notes pertaining thereto. The images from the telephoto camera were of greatest clarity, since this restricted the field of view to about 20 feet in width at the closest position. The wide-angle camera showed several hundred feet of the street and included the grandstand, trees, and sky as well. Telephoto shots of a single individual as in Fig. 10 were quite satisfactory. There was, of course, over the relay link a background of interference noise because of low signal strength.

Acknowledgment.—The assistance of Henry Rhea, Dr. G. Brown, and W. Beltz of RCA is gratefully acknowledged in testing the equipment on the 2.3-mile pick-up. The generosity of the Pasadena lodge of Elks in opening their club to television was greatly appreciated. The untiring work of the television staff, Thorp, Klein, Jury, Pitzer, Wyland, and O'Brien, and the coöperation of the radio broadcasting department under F. Kennedy are likewise acknowledged.

QUALITY IN TELEVISION PICTURES*

P. C. GOLDMARK AND J. N. DYER**

Summary.—*Present television standards specify certain factors which determine the appearance of a television picture only to a limited extent. Other factors, however, such as contrast, gradation, brilliance, and the shape of the scanning spot, are fully as important.*

A photographic method for producing artificial television pictures which permits varying several of these factors has been developed. Pictures are shown which were obtained by this method and which approach ideal quality within a given set of standards.

This paper is a summary of recent investigations and experiments aiming to determine the best possible television picture quality that would be available within the so-called RMA television standards.

Equipment has been designed to duplicate photographically the appearance of a television picture with predetermined characteristics, such as definition, contrast, and gradation.

The following factors chiefly determine the quality of a television picture:

(*1*) Definition.
(*2*) Contrast range.
(*3*) Gradation.
(*4*) Brilliance.
(*5*) Flicker.
(*6*) Geometric distortion.
(*7*) Size.
(*8*) Color.
(*9*) Noise.

Of the nine factors determining the picture quality only the first, definition, and the fifth, flicker, are subject to standardization, and these will be dealt with first.

Definition.—When viewing objects which are comparatively dimly lighted, such as television pictures, the iris of the human eye is ex-

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received May 3, 1940.

** Columbia Broadcasting System, New York, N. Y.

panded in order to allow maximum light to enter the eye, resulting in reduced visual acuity.

Under ordinary conditions the overall resolving power of the eye is limited to the spacing of the cones on the fovea, which has been found to be about 0.01 mm.[1] As a result the resolving power of the eye will not be better than 1 minute. Tests have shown that on the average the minimum resolving angle is between 1.3 and 1.5 minutes of arc at light intensities to be expected in television.

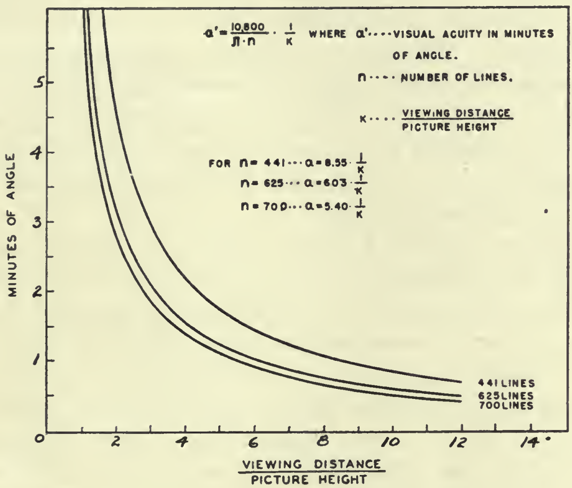

FIG. 1. Visual acuity *vs.* ratio of viewing distance to picture height.

For motion pictures the most satisfactory viewing angle, that is, the angle subtended by the eye of the observer and the edges of the picture in the horizontal direction, has been found to be not more than 20 degrees. This corresponds to 15 degrees in a vertical plane for a picture ratio of 3:4. Due to the limited angle of sharp vision, all parts of the picture could not be seen satisfactorily at the same time if the viewing angle were larger.

Visual acuity varies from one individual to another and so does the most satisfactory viewing distance. A relationship between visual acuity, number of lines per picture, and various ratios of viewing-distance-to-screen-height was developed on the assumption that the vertical and horizontal details are approximately equal (Fig. 1). Regardless of whether the line structure is apparent due to improper

scanning spot size or shape, this relationship must be applied in view of the limitation on detail imposed by the available frequency band of the television system.

The diagram in Fig. 1 indicates that for a 441-line picture and a visual acuity of 1.5 minutes, a viewing distance to height ratio of 5.7/1 is desirable. Design characteristics of modern motion picture theaters show that satisfactory viewing conditions are obtained up to distances as much as 12 times the picture height.

It is desirable to determine how much visual detail may be reproduced by a television system with a given number of lines and frequency response. This may be analyzed mathematically, but for some purposes it would be more satisfactory actually to produce an idealized television picture. Such pictures, though they could probably not be duplicated by commercial receiving and camera tubes today, would be very useful tools in indicating the capabilities of a given set of television standards.

The maximum definition that a television system is capable of reproducing is determined not only by the frequency response of the entire system but also by the receiving and transmitting scanning spots, the number of scanning lines and frames, and the fine detail contrast. Electron scanning beams of circular cross-section and non-uniform current distribution are ordinarily used at present in the camera and at the receiver. The shapes of these scanning spots, therefore, become important factors in determining definition. The effect of a particular frequency response characteristic on the fine detail has been shown to be the same as that of an equivalent scanning spot. For example, the effect of an infinitely narrow scanning spot and a given finite frequency characteristic could be duplicated by a properly designed scanning spot used with an amplifier with a flat response to an infinite frequency. Such a scanning spot may not always be physically realizable, particularly in cases where there is a sharp cut-off in the frequency characteristic of the electrical system (Fig. 2).

It has been shown that if the frequency response of a television system follows the shape of a probability curve ϵ^{-x^2}, the equivalent scanning spot distribution will follow a similar curve.[2] It was decided to use this type of characteristic to produce the synthetic pictures. The cut-off point of any frequency characteristic has been defined as the upper limit of a rectangular characteristic of equivalent area. Under present-day television standards the receiver band

width is limited to about 4.25 mc and the response must be zero at 4.5 mc. The pictures which have been produced have assumed a cut-off frequency as previously defined of 4.25 mc with a response characteristic which follows a probability curve. The closest approach to this characteristic which can be made with the present standards would follow the probability characteristic to the cut-off frequency and would then drop rapidly to zero. This would result in small oscillatory transients which would only be about ± 5 per cent of the peak signal value on scanning from a black to a white area. (It

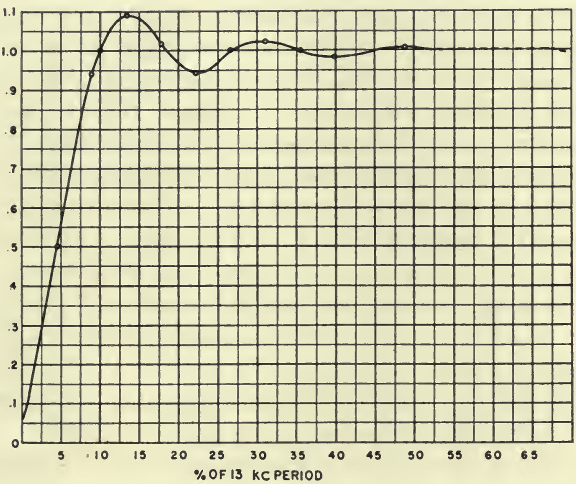

FIG. 2. Calculated response to suddenly applied voltage of idealized 75-kc low-pass filter.

must be noted that the transient may build up to larger amplitudes if the picture consists of a number of parallel vertical lines at the proper spacing.) It is difficult to say whether or not this is a desirable or tolerable condition since most practical experience up to this time has been with television systems where the scanning spots have been large enough to mask transients of this type which otherwise might be seen.

The frequency response characteristic of the electrical system today is only responsible for a small part of the total loss in detail if the 4.25 mc band width is being fully utilized. Major causes for loss of definition today are incorrect scanning spot shapes at the receiving tube and, to a lesser degree, in the pick-up tube. Low contrast in the fine

detail reduces the apparent definition at the receiver. Variation in spot size with current intensity impairs the resolution of the final image and limits the maximum useful brilliance of the picture.

Contrast Range.—It has been found that a projected motion picture or a good photograph can provide a satisfactory rendition of most subjects with a contrast range of about 35 to 1.

Measurements of present-day cathode-ray tubes as used in television receivers show that the maximum contrast range is usually about 30 to 1. (Such ranges are obtained only in darkened rooms and between widely separated areas on the tube screen.) The contrast range between two adjacent points on the screen is not ordinarily more than 10 to 1. Extension of the contrast range to 30 to 1 in the fine detail would certainly more than double the subjective quality of present-day pictures. Observations indicate that more contrasty pictures seem to create the impression of better definition.

The most important factors impairing a satisfactory contrast range are: halation on the fluorescent screen, curvature of the screen and reflections within the bulb itself.[3] The contrast range is reduced if extraneous light falls on the cathode-ray tube screen as is often the case under average viewing conditions. In order to extend the contrast range under such conditions it is necessary to increase the maximum brilliance of the picture.

It is important to realize that the resolution is also limited by incorrect scanning beam spot sizes and shapes. Cathode-ray tubes of today achieve fairly good horizontal resolution by employing a small round spot, the diameter of which is less than the theoretical width of one line. The theoretically correct shape for a spot would be that of a rectangle, its height being equal to 1/441 of the picture height and its width, that is, its dimension in horizontal direction, being a fraction of its height. Since the area of such an ideal spot is greater than that of the small circular spot, the maximum brilliance of the narrow rectangular spot of correct height would be greater by the ratio of the respective areas, provided the current densities remain the same.

Gradation and Brilliance.—It is ordinarily assumed that the eye response is logarithmic. A picture can not represent reality in all respects, and usually it is impracticable to reproduce the average brightness of the original scene. Under such conditions it is important that correct rendition of brightness differences be obtained over the entire contrast range. This condition is satisfied when the gradi-

ent of the television system is constant regardless of the brightness.

The gradient of a television system may be defined as the ratio $\Delta \log B_r / \Delta \log B_t$ where B_r is the brightness of the receiver cathode-ray tube and B_t is the brightness of the transmitted scene. The gamma of a television system is equal to the gradient over the straight-line portion of the $\log B_r$ *vs.* $\log B_t$ characteristic.

Television systems today do not necessarily maintain a constant gradient over the entire operating characteristic. This results in the appearance of crowding of the tone range in the blacks or whites, or both. Pictures have been produced in the laboratory where the

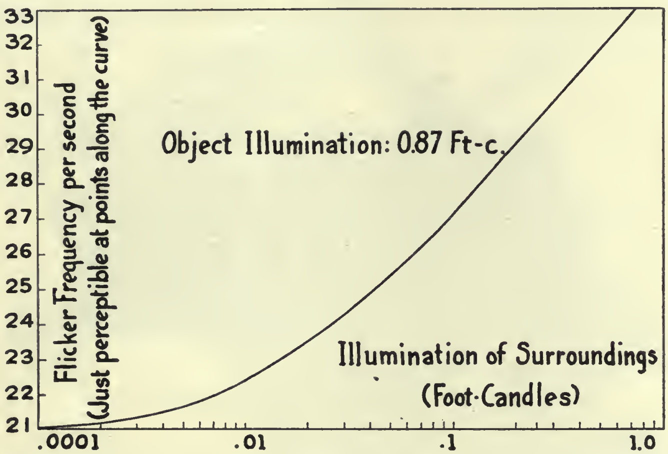

FIG. 3. Perceptible flicker frequency *vs.* illumination of surroundings.

gradation was approximately correct and it can be expected that an improvement in this respect may be achieved without great difficulty.

The average brightness of a television picture should probably be about 8 apparent foot-candles. This would correspond to highlights of the order of 17 apparent foot-candles, depending on the composition of the picture. Though visual acuity improves somewhat with brilliance, an increase in illumination of 2:1 will change only slightly the relationship between visual acuity and number of lines. An increase in picture brilliance will automatically extend the contrast range and improve the gradation.

Flicker.—It is recognized that the brilliance of present cathode-ray pictures is inadequate for viewing in undarkened rooms. Tele-

vision pictures scanned at a rate of 15 or even 24 frames per second (interlaced scanning), which do not display flicker up to approximately 6 foot-candles, will show conspicuous flicker at higher brilliancies. The frame repetition rate of 30 per second (interlaced) as used in television today is well justified because flicker is a more serious problem in television than in motion pictures for the following reasons: First, assuming that the integrated light is constant, flicker will increase in proportion to the ratio of the dark period to the light period.[4] Second, it is desirable to view television in undarkened rooms and therefore brilliancies greater than found on motion picture screens will be required. Third, the higher the illumination of the surroundings in which the television picture is viewed, the more flicker

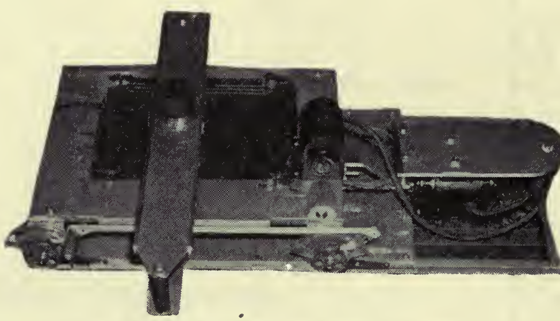

FIG. 4. Artificial television scanner.

will be perceptible. The diagram shown in Fig. 3, which is based on experimental results,[5] shows that with 0.001 foot-candle illumination of the surroundings and 0.87 foot-candle illumination of the picture under test, flicker just becomes perceptible at about 21 field changes per second. With the same picture illumination but with a surrounding illumination of 1 foot-candle, the field repetition rate has to be increased to 34 per second in order to eliminate flicker. Low frame frequencies can be employed successfully only in conjunction with a storage method which retains the received image for the duration of a complete frame (including the blanking period).

There is some difference of opinion as to whether a reduction in picture repetition rate may be desirable if complete storage were possible. There will be some sacrifice in the appearance of motion as the repetition rate is reduced, but with a given frequency band increased detail will result. When satisfactory storage methods are found ex-

periments will undoubtedly show the most desirable repetition rate under any given set of conditions.

Geometric Distortion, Size, and Color.—Geometric distortion can be caused by lens distortion in the cameras, scanning distortion in the cameras, scanning distortion, and curvature of screen at the receiving tube. The trend toward cathode-ray tubes with flat screens in conjunction with accurate scanning will eliminate most of the distortion existing at present.

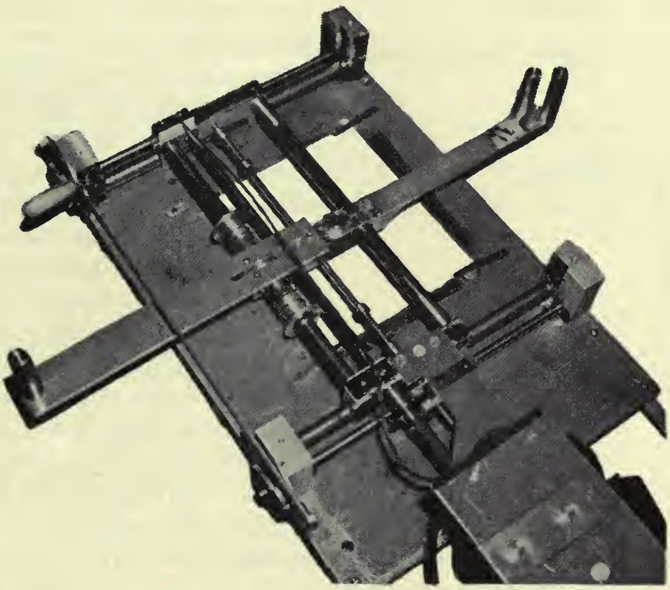

FIG. 5. Artificial television scanner partially disassembled.

The minimum height of a 441-line television picture is about 2 inches since it is determined by the minimum comfortable viewing distance of about 15 inches (Fig. 1). The upper limit is determined by how much viewing distance is available. Motion picture experience has shown that for minimum eyestrain the screen height should be not more than 0.27 times the viewing distance regardless of the amount of detail. This value is therefore independent of the number of lines in a television picture.

Most television picture tubes today have a screen material which is satisfactory from a color point of view, that is, highlights are repro-

duced as pure white. Though greater efficiency can be obtained from other than white screen materials, the latter is preferable for the sake of its color in projection tubes.

Artificial Television Scanner.—An apparatus was constructed to duplicate the behavior of an ideal television system by photographic methods. Positive transparencies of desired subjects were prepared on 8 $\times$ 10-inch glass plates. These positives were then scanned with a moving light-source and optical system, one line at a time, and were reproduced on a sensitized photographic plate. The horizontal scanning was motor-driven with automatic limit switches and braking. The change in the direction of scanning at the end of each line and the advancement in the vertical direction were manual, and the latter was adjustable for any desired number of lines. Alternate lines could be scanned in opposite directions since the defining apertures were symmetrical (Figs. 4 and 5).

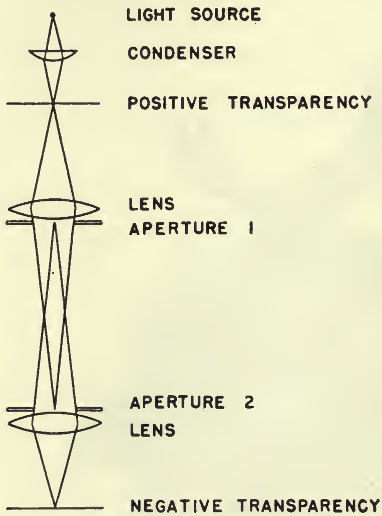

FIG. 6. Optical system.

The definition was determined by the apertures in the optical system. The optical system consisted of a light-source with a condenser lens above the positive plate to be scanned and two lenses of $^1/_2$-inch focal length assembled in a housing and located between the positive and the sensitive plates. Two apertures were used in the optical system with one aperture placed just above the lower $^1/_2$-inch lens and one just below the upper lens. The image of the positive was focused on the lower aperture which might be termed the frequency response aperture. The upper aperture represented the receiver or transmitter spot size and was focused on the photographic plate (Fig. 6).

The number of lines was determined by the size of the spot in the vertical direction and by the amount by which it was advanced vertically at the end of each line. The optical system was arranged to give a 2:1 reduction of the image of the upper aperture and a corresponding enlargement of the image focused on the lower aperture. This made

it possible to make the very small apertures twice the size they otherwise would have been.

Some of the fundamental requirements of apertures designed to reproduce the effect of a given frequency response have already been described. The ideal aperture of the ϵ^{-x^2} type would be rectangular and of a height equal to one scanning line with a light transmission across its width corresponding to a probability curve (Figs. 7 and 8; Fig. 8 shows aperture dimensions for the particular optical system described above).

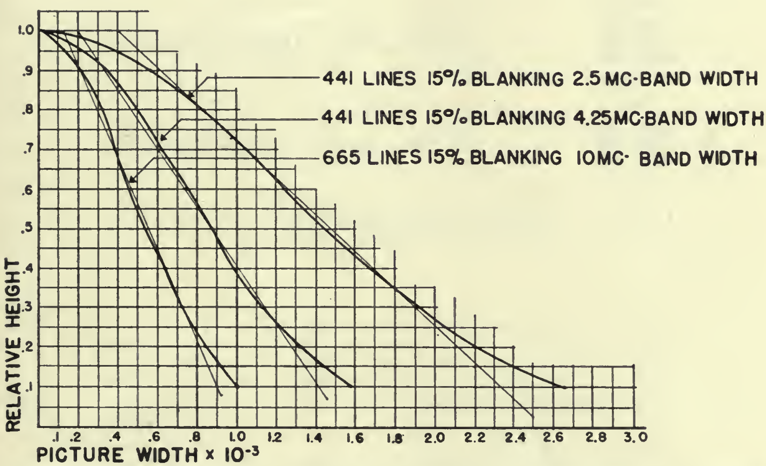

FIG. 7. Aperture shapes for duplicating receiver response based on response shaped like probability curve ϵ^{-x^2}.

Attempts were made to produce apertures by photographing large-scale models. However, it was immediately apparent that the dispersion of even the finest-grained emulsion could not be tolerated because of the great loss in light. An alternative approximation was to shape the leading and trailing edges of the aperture so that the desired characteristic could be obtained. The characteristic could be quite well approximated by assuming it to be a straight line. It was essential that the density in the vertical direction across a scanning line be constant in order to minimize the line structure. The aperture shape that immediately suggested itself was a parallelogram. A comparison between the theoretical aperture ϵ^{-x^2} and the parallelo-

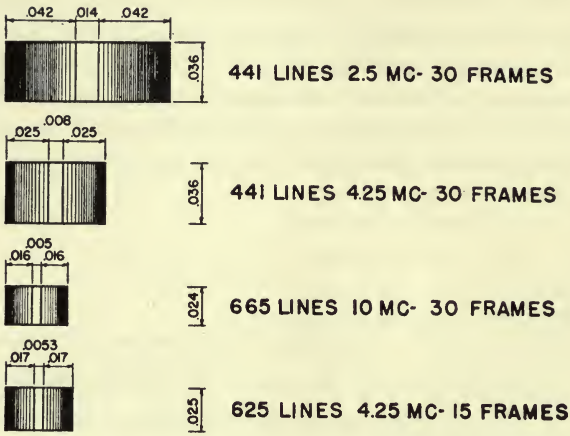

FIG. 8. Aperture sizes for duplicating receiver response based on probability function ϵ^{-x^2}.

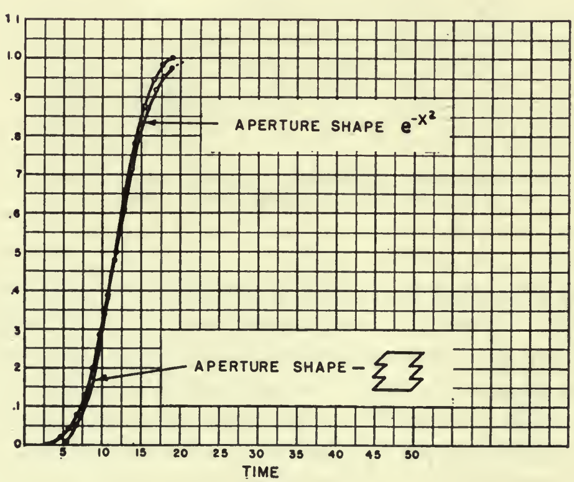

FIG. 9. Calculated aperture response for suddenly encountered white picture area.

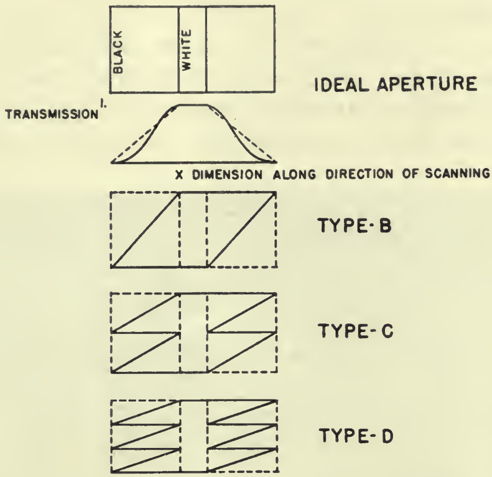

FIG. 10. Types of apertures for duplicating receiver response.

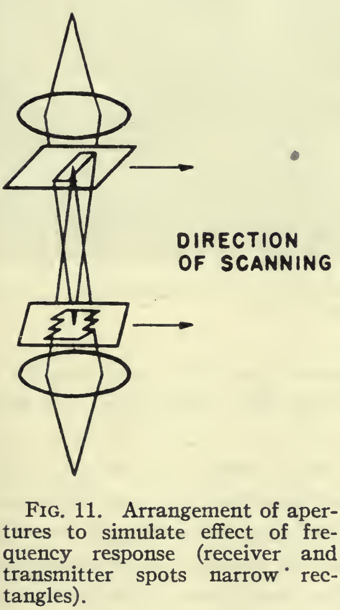

FIG. 11. Arrangement of apertures to simulate effect of frequency response (receiver and transmitter spots narrow rectangles).

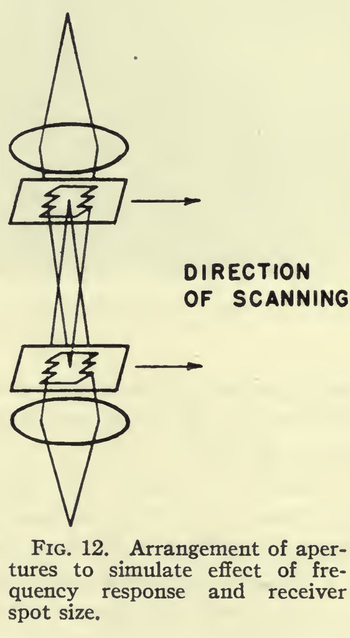

FIG. 12. Arrangement of apertures to simulate effect of frequency response and receiver spot size.

gram apertures which were used shows that there is little difference in their behavior (Fig. 9).

The parallelogram would give the desired effect when scanning across vertical lines, but on encountering a line tilted at the same angle as the edges of the aperture, it would produce too much detail. This effect could be minimized by dividing up the aperture into several

FIG. 13. Original photograph from which Fig. 14 was produced. (*Photo by Fairchild Aerial Surveys.*)

parallelograms. An infinite number of parallelograms would be ideal, but practically it was found that three would give adequate results (Fig. 10).

Simulated television photographs were made of several typical subjects and two conditions were studied with the aid of the scanner. The first condition is the very ideal situation where the receiver and the transmitter spots are rectangular slits exactly one line high and where the frequency response is duplicated by one probability aperture (Fig. 11).

For the second condition, which might be considered to be more realizable today, it was assumed that only the transmitting aperture was of the ideal narrow rectangular shape and that the receiving aperture, while considerably better than in most present-day tubes, was not ideal. The current in the transmitting scanning beam is ordinarily very low, and it can be expected that the ideal shape might

FIG. 14. Scanned reproduction of Fig. 13 (441 lines, 30 frames, 4.25 megacycles, slit aperture).

be approached. It was assumed that the receiving spot intensity could be made uniform in the vertical direction and approximately one line width high, but the horizontal distribution was the same as in the frequency response aperture (Fig. 12).

Reproductions of pictures produced by the artificial method are shown in Figs. 13 to 16. A 441-line scanning standard was used with a cut-off frequency of 4.25 mc (assuming 30 frames per second). Fig. 14 was produced with the apertures arranged as in Fig. 11 and assumed that the receiver and the transmitter spots were narrow slits,

exactly one line high. Fig. 13 is the original photograph from which Fig. 14 was made. The pictures shown in Figs. 15 and 16 were produced using the aperture arrangement of Fig. 12 and simulated a television system where the horizontal distribution of the receiving spot followed the ϵ^{-x^2} shape. The distribution across the spot in the vertical direction was uniform. Some of the pictures show spuri-

FIG. 15. Scanned picture (441 lines, 30 frames, 4.25 megacycles, ϵ^{-x^2} aperture).

ous patterns of the type predicted by Mertz and Gray, but it should be realized that this effect is not uncommon since it is produced by all halftone processes. Defects of this type will be less noticeable when objects are in motion.

Conclusion.—The synthetic pictures seem to indicate that television pictures as received today have to be improved a great deal before the capabilities of present 441-line standards are fully utilized.

The authors would like to express their appreciation of the large amount of work contributed to this project by Messrs. Doncaster, Hollywood, Piore, and the other members of the CBS Television Department.

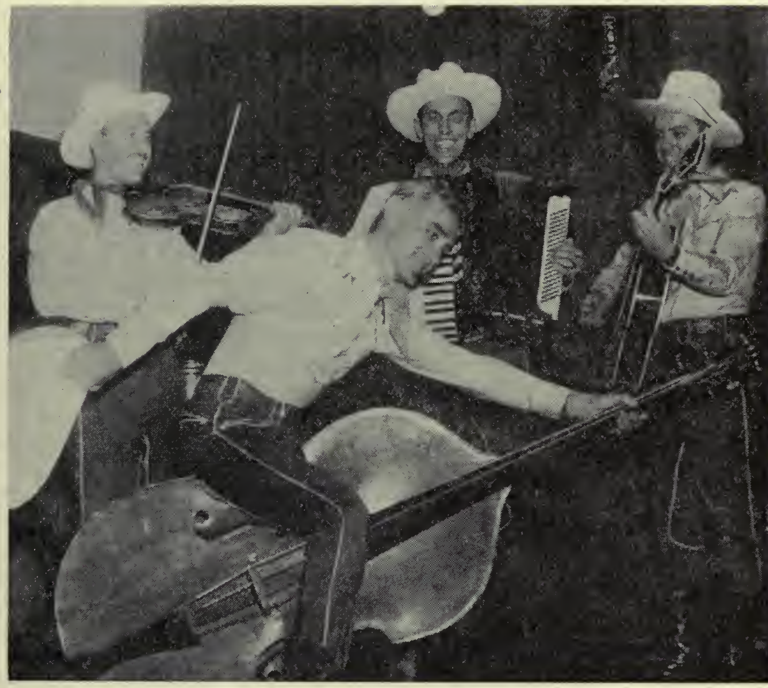

FIG. 16. Scanned picture (441 lines, 30 frames, 4.25 megacycles, ϵ^{-x^2} aperture).

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DISCUSSION

MR. F. H. RICHARDSON: We have just been told that television is next door to the theater. What is the prospect of serving the entire country through television in the theater?

MR. DYER: That depends upon much more than engineering. It obviously has a lot to do with economics. No one today is going to put money into a television network to cover the United States in the way that a group of chain theaters does, although the engineers probably have adequate and satisfactory methods for covering the country with television facilities. It is going to be a long time before that happens.

MR. BEERS: When the motion picture industry turned to sound-on-film it adopted the film speed of 24 frames a second. It has been said that even if that speed were not required for satisfactory reproduction of sound, the industry would still adhere to it on the basis of the improvement obtained in reproduction of motion. Is that fact or fiction?

DR. GOLDSMITH: As I understand Mr. Beers's question, if the motion picture industry were not concerned with adequate sound reproduction at 90 feet per minute, and if the film users and manufacturers were not interested in the additional film footage thus used, and if the sole criteria were excellence of picture quality, absence of flicker, and smoothness of depicted motion, would the industry still adhere to 24 pictures or 48 fields per second, rather than the supposed former practice of 16 pictures and 32 fields per second?

MR. DUBRAY: Sixteen pictures a second proved satisfactory for silent films. The film speed of 60 feet a minute was found to be the minimum speed necessary to eliminate flicker under normal screen brightness and with a view to economy of film.

MR. BEERS: I am not interested in flicker, but in the reproduction of motion. Is the improvement obtained in going from 16 to 24 frames, judged only from the standpoint of the reproduction of motion, worth the additional cost of making the change?

MR. DUBRAY: Camera and projector speeds are, of course, closely related, and for faithful reproduction the projector should operate at the same speed as the camera. Flicker is a major consideration for determining film speed. For a static object a speed of 60 feet a minute would be satisfactory. For rapidly moving objects, greater speeds may be advisable. Increases in screen brightness would call for greater operating speeds but, of course, there is a limit to acceptable film consumption.

Furthermore, camera and projector exposure times have great influence on the smoothness of projection. The greater the exposure time in relation to the time of occultation, the smoother and more pleasing the projected image will appear.

MR. GRIFFIN: Those who remember the projection of pictures back in the silent days will recall that pictures were not projected at 16 frames a second. They were projected more nearly at 18 or 20 frames a second—and more. But

under normal circumstances where good projection was required, it was decided by the Society that the projection of pictures at 16 frames a second was entirely too slow, and that the eye retained the impression of each succeeding picture. It was not solely on account of flicker, but because more frames per second were required to get the proper illusion of motion of a relatively fast-moving subject, that the projection speed was increased. So I should say that 30 to 40 frames per second now, if apparatus standards could be changed and the producers would be satisfied to use the amount of film required, would provide far superior projection to that obtained by present-day standards.

MR. CRABTREE: Unless the televised pictures which we are going to see this evening are much better than what I have seen, there is no question in my mind that the definition is not good enough to get by, at the present time. As has been shown, it is theoretically possible with 441 lines to secure better definition than is now being obtained.

What are the principal factors involved, and what must be done to achieve better definition with 441 lines?

MR. DYER: It would take a long time to go into those questions. The receiving tube is probably one of the most serious limiting factors. The scanning spot size and receiving tube are certainly two of the things that a person would attack first—the spot size changes according to the brilliance. The spot size can be very small if operated at low brilliance, but if we try to obtain better picture quality by increasing the brilliance, the picture quality immediately will suffer by loss in definition.

I do not know under what conditions the pictures you have seen have been shown; but in the home today, in many cases in large cities, reflections in the transmission path cause loss of detail having nothing to do with the television system, as such. That can be improved by modifying antennas and changing their locations. The transmitting equipment does not need to be as much of a factor in the loss of detail as the receiving equipment.

DR. GOLDSMITH: As a practical proposition, when everything is working properly in the system, you can take a page of a newspaper, for example, the *New York Times*, and hold it in front of the camera to fill the field. In the home you can then read everything down to, but not including, the 6-point type. Every headline is readable. That represents fairly good definition in a picture only $7^1/_2$ by 10 inches. Mr. Crabtree has evidently been unfortunate in his experience in that regard because present-day television close-ups show very fine detail.

MR. CRABTREE: I am speaking of what has been most recently demonstrated publicly by two of the larger manufacturers.

MR. DYER: At one time in our studios we made prints of a subject on 8-mm, 16-mm, and 35-mm film (the same print), and projected all three of these prints side by side on the screen, which was about 12 or 14 inches wide. Then we projected a television image of the same picture, in the same size. We asked a group of non-engineers to look at the pictures and decide how good they were and where the television picture stood in relation to the others. Discounting brilliance, it was found that there was no question that the television picture was better than the 8-mm film, but that it was not as good as the 16-mm. The test was not indicative of the type of picture we showed here tonight, because the receiving tube

was not capable of producing anything like the definition of these idealized pictures.

MR. BEDFORD: I would like to congratulate Mr. Dyer on effectively demonstrating that a satisfactory television picture can be reproduced with 441 lines when we learn how to do it. There is one point, however, of an academic sort, on which I would like to express a difference of opinion. He indicated, I believe, that if a picture were transmitted using a perfect storage device at the pick-up end of the system, and a perfect storage device at the receiving end of the system, even though the picture were transmitted at the rate of 15 frames a second, there would be neither jerkiness of motion nor flicker. If I understand correctly, what would happen is that the picture would be blurry due to the storage effect at the transmitter, but there would also be jerkiness because the blurry picture would be reproduced as a series of stills. So I believe we would have both jerkiness and blur in that case. If I should pick an ideal system, I believe it would be better to have an instantaneous pick-up device and complete storage at the receiver.

MR. MAURER: A number of years ago I had occasion to work with an inventor who had devised a continuous projector and camera with which he could photograph at any speed he desired. With this camera he obtained a continuous record of everything that went on, subject to the blurring that would occur. In other words, there was no part of the cycle during which his lens was not making an image on the film. When he took pictures of athletes going through rapid motions and projected them with a similar continuous projector mechanism, the effect was generally smooth and surprisingly satisfactory, even at as low a speed as 10 frames a second. But when he used the same continuous projector with a picture that had been taken with the usual intermittent type of camera, where each image was sharp, as soon as the speed dropped below about 20 frames a second a certain jerkiness was noticeable, which became quite obvious at 16 frames a second. The transition or jump from one fixed stage of the motion into the next fixed stage was a great deal more objectionable, in my opinion, than the complete blur that occurred by having the image show everything that took place.

DR. GOLDSMITH: The idealized type of projector which we are discussing is the non-intermittent constant-brightness projector. In this form of an "ideal" cinematic system, a camera which took a picture with the brightness of the picture constant on the film throughout the photographic cycle and a projector which projected the picture with constant brightness throughout the rectification cycle would be used. With such a combination, it is a fact that one can tolerate a lower number of frames per second, provided there is really constant-brightness non-intermittent projection, and provided that one is using a type of studio and projector lighting that is difficult to define, but consistent with that mode of presentation.

On the other hand, I can not quite agree, from my own experience, that one can go down as low as 20 frames a second and get away from flicker on a bright picture, for example, of a fencing match where there are brilliant and separated reflections on a rapidly moving foil.

MR. MAURER: I agree with that. The action in the pictures I saw was running, diving, and swimming.

MR. FRIEDL: I am interested in Mr. Dyer's comment about the quality of the television picture as compared with 8-mm, 16-mm, and 35-mm film pictures. I

heard the statement at a previous meeting, but not so broadly. The previous reference was to the definition of the television image, as compared to the 8-mm and 16-mm.

Inasmuch as a number of factors contribute to the "quality" of a picture, there was a question as to whether or not definition alone was being judged as a measure of quality. As a comparison of picture for picture on an overall quality basis, a specific question was asked; *i. e.*, if you were to project an 8-mm or 16-mm film on a screen adjacent to and of the same size as a television image, would the television image be selected in preference to the 8-mm or 16-mm?

The last time the question was raised, I believe it was answered by saying that it is comparable in definition only—not in flatness of field, not in contrast, and not in brilliance. "Definition only" is a nice rule-of-thumb comparison to make, but I am afraid it will leave a lot of people expecting too much of television. I am an 8-mm "fan," and I have yet to see a television image that compares with my 8-mm pictures.

MR. DYER: The test I described was made by reducing the brilliance of the 8-mm and other projectors to the brilliance of the television picture. If you accept that limitation the layman's answer seemed to be that he preferred the television image to the 8-mm.

MR. FINN: Considering the experience the motion picture people have had, I think it ill becomes a group of men who must notice every day the wide variance in density among reels of a given picture to criticize severely a new art for lack of detail. From my point of view I think the television images are fine; and when I see the change-overs in some of our *de luxe* picture houses, with all our past experience, I am inclined to think they may be better.

MR. BEERS: With regard to the comparison between the television image and that obtained from motion picture film, I believe I am the one who answered the question at the previous meeting. The reason why the comparison was made on the basis of definition only was that definition is the factor that is primarily determined by the standards we are using. Picture quality, contrast, *etc.*, are characteristics on which we have sufficient information to know that we can control them, and, in the future, improve them to the point where we feel they will be comparable with the results we get from film.

A NEW METHOD OF SYNCHRONIZATION FOR TELEVISION SYSTEMS*

T. T. GOLDSMITH, JR., R. L. CAMPBELL, AND S. W. STANTON**

Summary.—*Line and frame scanning frequencies in an all-electronic television system need not be frozen to a standard giving limited definition performance if the synchronizing system is arranged so as to allow flexible operation. Automatic operation of receiver synchronizing circuits at variable line and frame frequencies is made possible with the aid of a new type of synchronizing wave-form. Synchronizing standards which permit both flexible and automatic operations are discussed. Transmitter synchronizing apparatus for flexible synchronizing standards, receiver circuits for both non-automatic and automatic synchronizing operation are also discussed, and a "transition" type receiver for operation on both old and new types of synchronizing signals is briefly described.*

While 441-line television represents a good starting point for public service in a restricted experimental manner, it is quite likely that wide public acceptance will demand, among other things, increased definition performance. With present-day screen projection as a standard of comparison, it appears certain that better definition is a "must" for television in the near future. To obtain pictures having better definition it finally becomes necessary to add more scanning lines, which requires a change in either horizontal or vertical scanning frequencies, or both. A logical improvement, therefore, is a synchronizing system that will allow a television receiver to operate at various line and frame frequencies without requiring changes in circuit constants.

Before proceeding to the subject in point, a brief outline of the principles of television synchronization will be in order. Present practice is to send the line and frame synchronizing pulses mixed with the video signals over a common channel. For line scanning a horizontal synchronizing pulse is transmitted during the flyback period of each scanning line, and a vertical synchronizing pulse is transmitted during the vertical flyback period. These two synchronizing signals are formed at the transmitter, and are first mixed

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** Allen B. Du Mont Laboratories, Passiac, N. J.

together and then mixed with the video signal to form a composite television signal. At the receiver it is necessary first to separate the synchronizing signal from the video, and then segregate the horizontal and vertical synchronizing components from the separated synchornizing signal. A television channel therefore has three distinctly separate signals which must be transmitted simultaneously without interaction and then utilized separately at the receiver.

It is possible, of course, to permit some interaction and consequent imperfections in synchronizing signals by employing weak synchronism at the receiver. Weak synchronism, however, is not desirable in a flexible system because of the necessity of having synchronizing controls at the receiver. These controls are usually a fine frequency adjustment on the sweep oscillators, and unless synchronizing action is very positive, they are in need of adjustment frequently.

If the synchronizing signal is such that it will permit positive synchronism without distortion effects due to incomplete isolation, the synchronizing controls at the receiver can be eliminated. A further step is to do away with the self-oscillating feature of the sweep circuits, so that the frequency of receiver scanning is entirely dependent upon the synchronizing signal being transmitted. This latter step is called "automatic synchronization." In a strict sense, the term "automatic synchronization" is applied to receiver circuits wherein there is no scanning action unless the synchronizing signal is being received. However, it is possible, with proper synchronizing signals and choice of circuit constants, to operate self-oscillating sweeps so that they will remain synchronized over a reasonable range of scanning frequencies.

AUTOMATIC SYNCHRONIZATION

Automatic synchronization, however, provides for flexibility as well as positive synchronism because the circuits used at the receiver need not be of the self-oscillating type. This simplifies the control-panel problem for the lay-user in that there is no perplexing disintegration of the picture due to the loss of synchronism such as in the self-oscillating type of circuit when the sweep-frequency controls are out of adjustment.

In the self-oscillating type of sweep circuit the oscillator is tripped by the incoming synchronizing pulse, which times the discharge of the oscillator used to control the discharge tube. Because of the blocking action of the oscillator, it is non-receptive to incoming

signals except in the region of the firing interval. This phenomenon should be kept in mind, for in it lies the main advantage of an oscillator as a means of initiating sweep discharges.

The usable portion of the oscillator discharge pulse that is used to control the discharge tube resembles closely the shape of the transmitted synchronizing pulse. It is thus seen that the oscillator portion of a self-oscillating sweep circuit serves as a combination buffer and filter circuit. This buffer action has been necessary for two reasons, *viz.*,

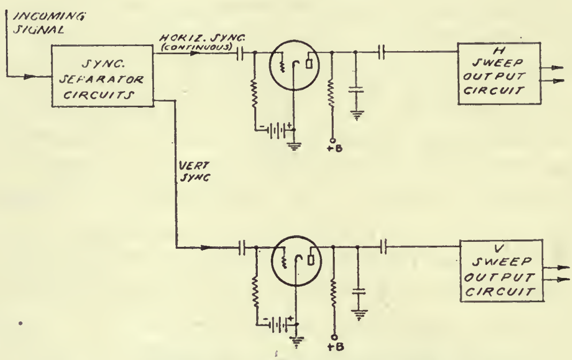


FIG. 1. Basic automatic synchronizing circuits.

(*1*) Imperfections in the received synchronizing signals, these being due to:
   (*a*) Incomplete isolation of horizontal and vertical synchronizing signals, and/or distortions in the isolated signals introduced by the isolating networks.
   (*b*) Incomplete removal of the video component from the synchronizing signal.

(*2*) Nullification of noise disturbances between synchronizing intervals, due to the well known blocking effect.

In Fig. 1 is shown a circuit for automatic synchronization of receiver scanning. The circuit is essentially the same as is used for self-oscillating sweeps from which the oscillator circuits have been removed. Vertical and horizontal synchronizing pulses, having been isolated in the synchronizing separator, are applied to their respective saw-tooth generators directly. A proper choice of time constants in the discharge circuits provides for a sufficiently linear saw-tooth output over a satisfactory range of scanning frequencies. It will be seen that the output voltage of the discharge circuits will

vary inversely with the frequency of the applied synchronizing pulse. A gain adjustment, either of the manual or automatic variety, must be provided to hold the required scanning amplitude over the desired range of frequencies. This change in amplitude is not considered a disadvantage, however, since the picture remains synchronized, and it becomes quite simple for the user to diagnose the difficulty. In fact, self-oscillating circuits require the same amplitude control, as well as a frequency adjustment if they are to be flexible.

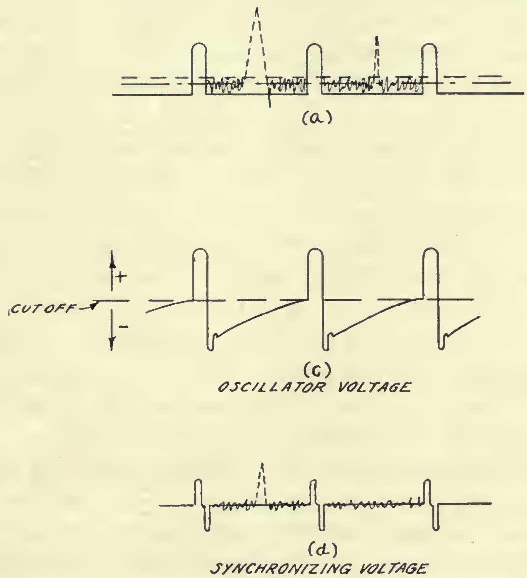


FIG. 2. Synchronizing and oscillator wave-forms.

The effects of noise upon these circuits is explained by means of Fig. 2. Assuming that the discharge tube is biased so that it is actuated by as much of the incoming synchronizing wave as is feasible, Fig. 2(a) shows that a pulse of noise (the dotted portion) will cause the circuit to fire prematurely and mistiming of discharge will result. In Fig. 2(c) is shown the wave-form typical of the blocking oscillator circuit, while Fig. 2(d) shows the synchronizing wave-form applied to the oscillator circuit. The highly negative signal occurring immediately after discharge acts to block the circuit for a considerable portion of the period before the occurrence of the

next pulse. By means of an inverse feedback circuit it is possible to cause blocking in a similar fashion in an automatic sweep circuit. Thus the automatic type of sweep circuit can be made to have noise characteristics substantially identical with those of the self-oscillating type of circuit.

SYNCHRONIZING SIGNALS FOR AUTOMATIC SYNCHRONIZATION

Automatic synchronization can be accomplished only with good isolation of synchronizing pulses at the receiver. It follows, therefore, that the synchronizing signal transmitted should be of such character that it can readily be broken down into horizontal and vertical signal components, each independent of the other although they have been transmitted as a composite synchronizing wave.

The isolated horizontal synchronizing pulses must be a continuous wave-train of homogeneous pulses entirely free from any low-frequency component in the region of the vertical pulse interval for best performance conditions of automatic horizontal synchronization.

Automatic synchronization of the vertical sweep circuit is even more complex in that not only must a pulse be separated entirely clear of the horizontal pulses in order to insure proper interlace at the receiver, but it must be free from low-frequency variations such as line surges, *etc.* This operation is further complicated when the vertical synchronizing pulse is designed to have a minimum effect upon the horizontal synchronizing signals.

Since automatic synchronization utilizes nearly all the synchronizing information that is transmitted, it can be seen that the signal applied to the respective circuits must be of good quality. This means that the video component must also be well separated from the synchronizing signal. Amplitude separation as a means for removal of the synchronizing component from the video component has been found to work satisfactorily for automatic synchronizing receiver operation. Care must be exercised, however, in the design of the amplitude-selective networks in order to maintain adequate separation over a reasonable range of total signal level.

A brief discussion of some of the synchronizing wave-forms employed in the past will enable a clearer understanding of the discussion to follow.

In Fig. 3, some of the more commonly known types of synchronizing wave-forms that have been in use at some time or other in the past are shown.

Wave-form *a* shows a form of amplitude selection for vertical synchronizing which was first advocated by Vance, a modification (dotted wave) of this being later proposed by Philco. The chief disadvantage here is that a separate amplitude level must be maintained for the vertical synchronizing pulse, and it is therefore wasteful of transmitter power. Furthermore, the vertical pulse interval is considered to be too short for satisfactory operation.

Wave-form *b* shows the type of pulse that was used to overcome the difficulties previously encountered with *a*, and here the difficulty is introduction of distortion in the horizontal synchronizing wave-train in order effectively to transmit the vertical. With this type of pulse, the so-called "flywheel" action of the sweep oscillators was

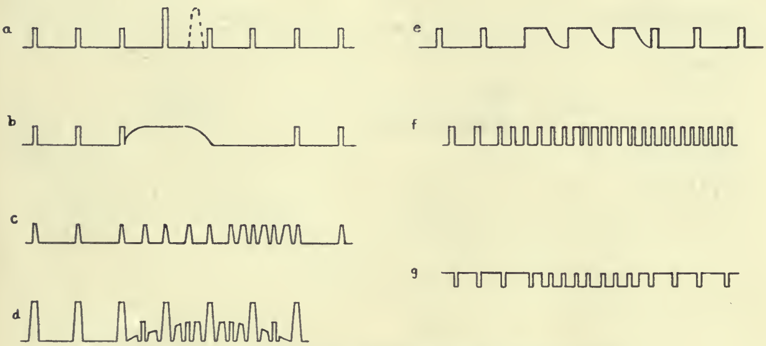


FIG. 3. Experimental synchronizing wave-forms.

utilized to keep the horizontal circuit in operation during the vertical pulse interval. This method of operation was unsatisfactory, however, in that horizontal synchronizing stability was extremely poor.

Wave-form *c* shows a means of transmitting continuous horizontal synchronizing by means of a chopped or serrated vertical pulse. Also here is shown the introduction of the equalizing pulses along with the vertical pulse for the purpose of improving the interlacing characteristics. This type of wave gave distortion of the horizontal synchronizing pulses during the vertical pulse interval due to the presence of high-frequency components in the vertical pulse.

Wave-form *d* (Fig. 3) shows a method similar to *c*, except that an amplitude separation is employed in order to obtain continuous horizontal synchronizing. This has practically the same disad-

vantage as *a*, and it is considered a workable system. Two methods of selection are employed as a means of isolating the two signals, amplitude for the horizontal, and frequency selection for the vertical.

Now, in wave-form *e* a method is shown for obtaining continuous horizontal synchronizing without resorting to amplitude means. This is probably the most effective attack to the synchronizing problem up to this time, and is due to Percival and Browne of E. M. I. Continuous horizontal synchronizing may be obtained by utilizing the steepness of wave-front of the sections of vertical pulse.

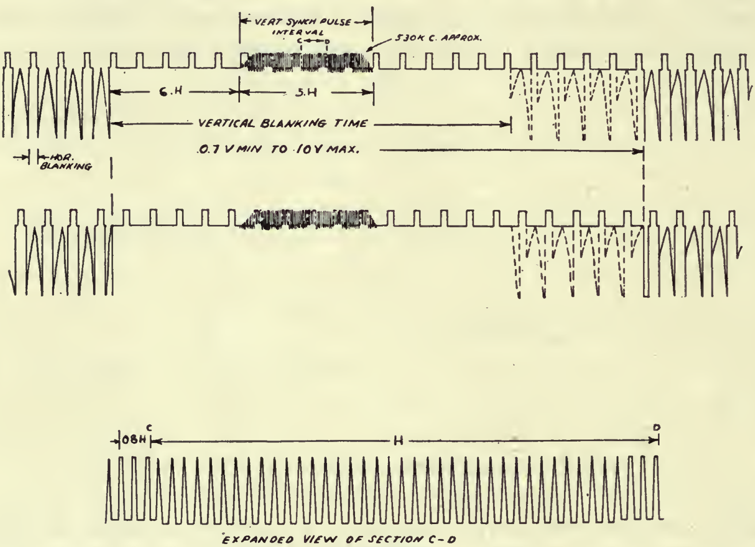


FIG. 4. Du Mont synchronizing wave-forms.

The RMA type *T111* pulse is shown in wave-form *f* (Fig. 3), and it will be seen that this is a combination of the E. M. I. Marconi standard (wave-form *g*) plus the equalizing pulses shown in *c*.

The RMA type of pulse, however, does not lend itself readily to adaptation to automatic synchronizing circuits. While it is possible to obtain a continuous horizontal synchronizing signal from this type of wave, the presence of equalizing pulses, plus the low-frequency components during the vertical pulse interval, does not provide a pure horizontal synchronizing wave-train such as is desirable. The resulting unwanted low-frequency components cause transients in

the horizontal circuit when it is being driven, which give rise to distortion of the scanning pattern at the top of the picture. Isolation of the vertical synchronizing to a degree where it is possible to utilize the pulse to drive automatic circuits is accomplished only with considerable difficulty.

The type of synchronizing wave found to be most satisfactory for automatic synchronizing purposes is shown in Fig. 4. The vertical pulse is transmitted in a series of high-frequency pulses which are mixed with continuous horizontal synchronizing for transmission, and subsequently separated at the receiver by simple filter circuits.

This form of synchronizing signal has been found to have decided advantages when it comes to isolating the two components at the

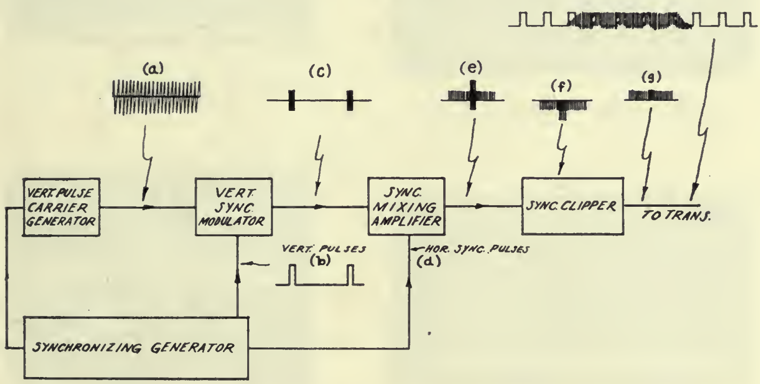


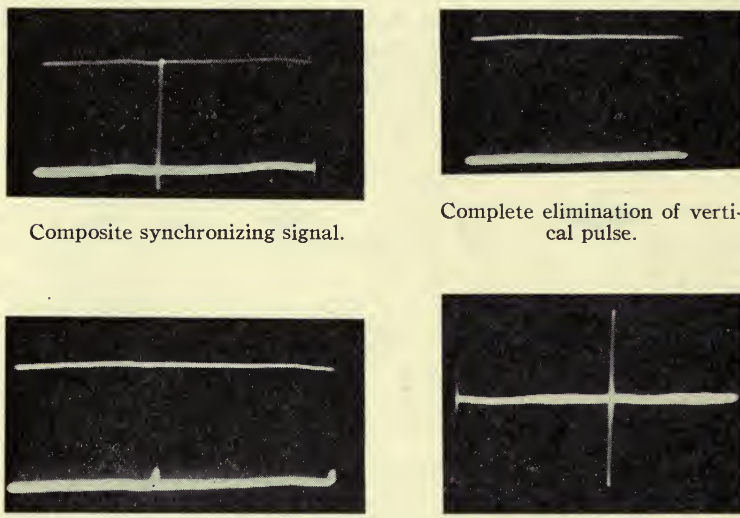
FIG. 5. Synchronizing generator for Du Mont synchronizing.

receiver. The vertical synchronizing signal is eliminated from the signal applied to the horizontal circuit by means of a wave-trap. This selective circuit is used to isolate the vertical synchronizing signal which then may be applied to the vertical sweep circuit either directly as a radio-frequency signal or detected and subsequently applied to the circuit.

The production of this type of synchronizing wave is quite simple when compared with formerly used systems. Fig. 5 is a block diagram of synchronizing pulse-forming circuits. To obtain the vertical pulse, the carrier-frequency is first developed in a frequency multiplier circuit. This produces a carrier *a*, harmonically related to the horizontal synchronizing frequency, which is an important factor as will be shown later. The carrier is then electronically keyed

by means of pulse *b* during the vertical pulse interval, the resulting signal being as indicated in the figure at *c*.

This signal is then mixed with the horizontal synchronizing wave-train *d*, which results in the signal shown at *e*. Next, the lower part of the vertical pulse envelope is "clipped" off (*f*), so that the resulting vertical synchronizing wave is a series of rectified pulses at the carrier-frequency. This latter operation is necessary in order to prevent the lower half of the envelope from extending beyond the



Composite synchronizing signal.

Complete elimination of vertical pulse.

Partial elimination of vertical pulse.

Vertical pulse free of horizontal pulses.

FIG. 6. Oscillograms of isolated synchronizing wave-forms.

picture "black level." It will be seen that an added component is obtained during the horizontal pulse interval, and, also, the negative portion of the vertical synchronizing carrier cycle subtracts from the horizontal pulse. The additive components may be "clipped" or "saturated off" without detrimental effects to the synchronizing performance. The resulting wave-form is as shown at *g* (Fig. 5). Upon removal of the 530-kilocycle component from the synchronizing signal the horizontal pulses are restored substantially to their original shape, and thus the resulting horizontal wave-train is continuous.

RECEIVER CIRCUITS FOR AUTOMATIC SYNCHRONIZATION

In Fig. 6 are shown oscillograms of the composite synchronizing signal as received, and the two separated components. It will be noted that the horizontal synchronizing pulse is entirely free of the vertical pulse, and the isolated vertical wave is devoid of horizontal synchronizing. Fig. 7 shows the frequency characteristics of the circuits used for horizontal and vertical synchronizing selection.

The isolated vertical synchronizing pulse is sufficiently free of unwanted disturbances so that it may be used to trigger a rather

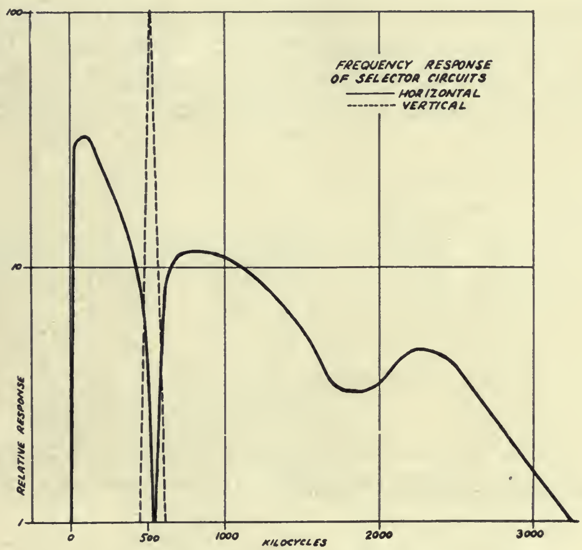


FIG. 7. Synchronizing selector network characteristics.

simple form of sweep system. Fig. 8 shows a "gas discharge" type of saw-tooth generator that operates quite satisfactorily. The gas tube is operated with a negative cut-off bias so that the circuit fires only when radio-frequency signals are applied to the grid. The saw-tooth output from the plate circuit is independent of input signal variations in amplitude or wave-form.

A schematic diagram of the receiver sweep circuit using automatic synchronization circuits is shown in Fig. 9. Both vertical and horizontal sweep circuits are of the non-oscillating type, and consequently will follow any frame or line frequencies that it is desirable to transmit.

Under no signal condition, there is no scanning voltage generated, and therefore it is necessary to remove the spot from the screen to prevent burning. There are several methods for accomplishing this protection, and at present it will suffice to say that the absence of scanning signals operates a device that prevents the electrons from reaching the fluorescent screen.

For noise-free operation this system uses the principle of blocking previously explained, together with a limiting device that prevents the noise from exceeding a predetermined amplitude.

Generally speaking, the horizontal synchronizing channel is more susceptible to noise effects, and anti-noise precautions are necessary in order to operate at locations where the noise level is high. Because of the comparatively narrow band employed for the vertical pulse, the noise problem has not been found to be serious in this

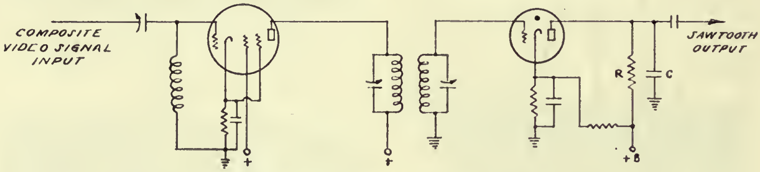


FIG. 8. Synchronizing circuit using gas triode.

channel. There are, however, several worth-while anti-noise circuits that could readily be applied to the vertical synchronizing channel.

RECEIVER CIRCUITS FOR BOTH AUTOMATIC AND NON-AUTOMATIC SYNCHRONIZING SIGNALS

In the foregoing a completely flexible and automatic system of synchronization has been described. In order to utilize transmissions operating at the present time on non-flexible standards, as well as future transmissions at improved standards, a "transition" type of receiver becomes necessary. The synchronizing circuits for such a receiver are shown in Fig. 10. With a receiver of this type, semi-automatic synchronization can be employed and still provide satisfactory operation on both old and new types of synchronizing signals.

During the time when some stations are transmitting the RMA

type of synchronizing signal and others are transmitting the radio-frequency vertical pulse synchronizing signal, it is going to be necessary to provide receivers with local oscillators and separator circuits capable of utilizing either type of pulse. Eventually universal adoption of the new synchronizing signal will enable receiver manufacturers to make full use of the advantages of the Du Mont signal with an entirely automatic set of sweep circuits. In the transition set there is still need of sweep adjustments for sweep speed, and as a practical circuit a two-position switch chooses either of two groups

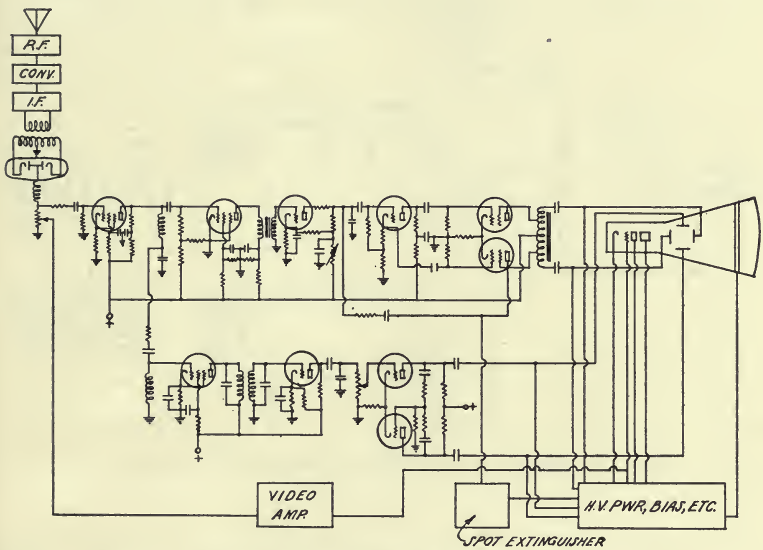


FIG. 9. Automatic synchronizing receiver circuits.

of potentiometers which can be set independently of each other, say, for 441 lines, 30 frames, and for 625 lines, 15 frames.

Satisfactory, though not the most efficient, circuits are available to use either RMA or Du Mont synchronizing pulses without switching except for sweep speeds. However, when all transmitters eventually use the radio-frequency vertical pulse type of signal, the proper tuned circuits for maximum selectivity of the 500 kilocycles vertical information will yield superior stability, and interlace then can be obtained in the temporary transition type of receiver.

CONCLUSION

The tests of this synchronizing signal show that it is thoroughly adequate for flexible operation. However, it is quite apparent that other components of the transmitting and receiving systems today limit the definition that can actually be achieved. Nevertheless, as the other components are improved, with such a system in operation as described above, the much-needed improvement in definition can be achieved gradually without necessity of complete replacement of equipment.

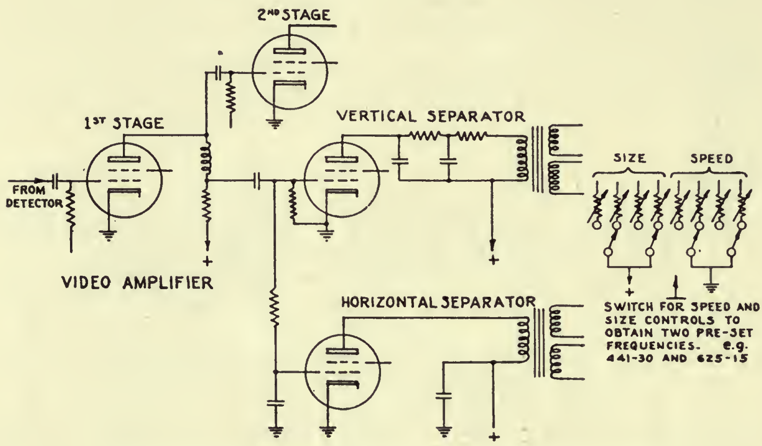


FIG. 10. Semi-automatic synchronizing receiver circuits.

The radio-frequency pulse type of synchronizing signal described above would seem to possess the following advantages over previously described methods of transmitting the synchronizing information:

(*1*) Ease of generation at the transmitter.
(*2*) Ease of separation at the receiver.
(*3*) Adaptability for use with simple "automatically synchronized" receivers, permitting reception from "high-definition" stations as well as "low-definition" stations, without the necessity of a service-man to readjust synchronizing and speed controls, and, more important, permitting increases in vertical definition as the art advances without necessitating replacement or modification of receiving equipment.

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REMOTE CONTROL TELEVISION LIGHTING*

W. C. EDDY**

Summary.—*The remote control lighting system now in use in the television studios of the National Broadcasting Company presents a completely new approach to the studio lighting problem.*

A new series of overhead units, mounting inside-silvered incandescent lamps, comprises the foundation lighting equipment which can be controlled in rotation, tilt, and elevation from an operating platform.

Flexibility has been incorporated to allow the lighting engineer to arrange the lighting to his satisfaction and to change the lighting completely without interrupting the program.

The units themselves have been designed around the specific requirements of the television cameras, and show under test a satisfactory efficiency both as to power consumption and dissipation of heat. The weight, of the order of 13 pounds per kilowatt, coupled with the extreme flexibility incorporated into the mechanical arrangement, appears to have solved the physical problem of installation.

Lighting personnel requirements are substantially reduced, and with the major part of the installation now attached to the overhead gridiron, additional valuable floor space has been given over to the cameras.

Illumination levels as high as 2400 foot-candles can be created on an average set, but due to general improvement of both camera tube and circuits, it is seldom necessary to exceed 800 foot-candles in foundation light.

Combining flexibility with economy of operation it appears that this new lighting system has solved many of the problems of illumination in a television studio.

In view of the experience so far obtained from our experimental television program service, it is now possible to analyze critically the lighting equipment used in the television studios of the National Broadcasting Company at Radio City. This equipment, while considered by some to be radical in design, is the result of steady developmental work initiated during the RCA television field test in 1935. At that time it was apparent that a television stage would require an unusually high level of illumination, but beyond that we were left to guess the trend that television program technic would take and the

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 20, 1940.

** National Broadcasting Company, New York, N. Y.

demands that it would make on our lighting equipment. It was to be expected then that our original lighting installation should be similar to that used on the smaller Hollywood sets. This equipment did produce illumination which at the time was considered satisfactory, but with the advent of multiple stages it was apparent that lighting was one of the problems which would seriously complicate the advance of program work if continued along these lines, because television had developed a technic entirely different from that used in motion pictures.

FIG. 1. A stage set-up in the television studio.

Specifically, our original equipment consisted of the usual array of focusing spots, scoops, broadsides, and rifles, all floor-mounted and all taking up floor space which should have been allotted to camera movement (Fig. 1). With the increase in size of the sets came an increase in the equipment and personnel required for operation, all of which further cramped the proper movement of the cameras. It was more to relieve the congestion and reduce the active personnel on the floor than to improve the lighting that a rearrangement of this equipment was undertaken. Installation of a portion of the units on a gridiron overhead was our first alternative, but the steady demand for still bigger sets requiring more light soon led us into an arrangement of fixed-focus lens lights arranged in a semi-hemisphere over an

area providing for a single set (Fig. 2). This addition, creating as it did a diffused foundation light of approximately 1000 foot-candles on all portions of the set, allowed us to utilize the focusing portable equipment for modeling and effect work, but such a fixed array did limit the program possibilities to a single set. The ever-increasing program demands for a multiple-set studio indicated that we had not yet evolved a satisfactory answer to the lighting problem. The equipment then in use to illuminate the single set was taxing the power input to the studio, so our attention was turned to the design of a more efficient lighting system rather than additions to the already heterogeneous assortment already acquired.

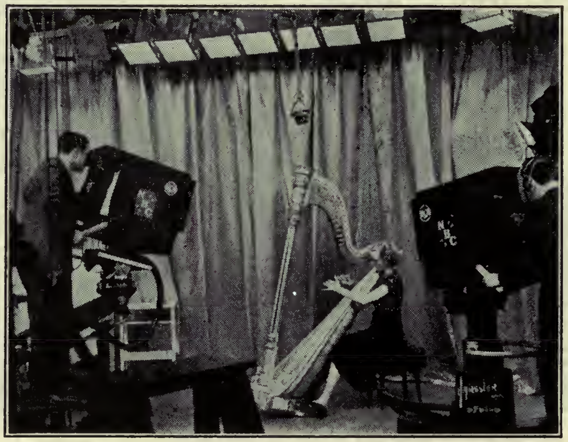

FIG. 2. Illumination by battery of 500-watt units.

The inside-silvered incandescent lamp proved to be a logical starting point and an experimental installation of six lamps was designed and installed in the Radio City studio. A substantial gain in useful light for a given amount of power was immediately apparent, and steps were taken to substitute units of this type for the original equipment. The constructional data on these units have already been presented before the Society[1] and we shall therefore limit our description to a pictorial review.

Our original unit, called the "single six" (Fig. 3), was composed of six 500-watt bulbs mounted in line on an adjustable arm. This equipment produces at a distance of four feet or greater a sheet of

diffused light, satisfactory in spectral quality for the television camera.

The "double three" (Fig. 4), a modification of the "single six," was found to be adaptable in the studio both as to maneuverability and the characteristics of the light-beam produced.

The "single three" (Fig. 5), one-half of the standardized "double three," is mounted vertically on an adjustable floor stand and is utilized for strip lighting and background illumination. In this case the narrow sheet of light works to our advantage in illuminating backgrounds without endangering the foreground modeling.

FIG. 3. The single-six mounting.

The "double three," less its supporting arm and mounted on a portable floor-stand, becomes the equivalent of the broadside, producing three kilowatts of directed, diffused light in a rectangular pattern (Fig. 6). Two of these units are normally used in any television production, the major part of the modeling or cross-lighting on the set being accomplished with these lights.

A "single three" mounted horizontally on the remotely controlled pedestal becomes the portable footlight (Fig. 7) which is brought into play in sequences demanding such illumination. In this case the operator remains well behind the camera and manipulates the lights with controls brought out to the operating handle.

Overhead at either end of the studio we have two master modeling units (Fig. 8) which can be swung through 360 degrees and tilted through 180 degrees. These units are the largest in the studio and can be considered as all-purpose lights, although their specific duty is, as their name implies, to establish the modeling angle of the light on the set.

The basic light of the entire installation is of course the remotely controlled "double three" (Fig. 9), of which type we have twenty-three installed on the gridiron in the studio. Before going into the details of this unit, let us take up the story chronologically in order better to bring out the need for such a device.

FIG. 4. The double-three unit.

Observation of the studio temperature and lighting loads in the early stages of our adoption of inside reflector lamps confirmed our assumptions as to the choice of this light-source. We at last had light available for the larger and more complicated sets demanded by program requirements, with neither the electrical load nor the studio ambient temperature registering a marked increase over the average operational mean of previous months. We were able to produce more light with less power. We were able to direct our light manually on more than one set, even though such a change did require time and personnel. The ambient heat problem had been reduced to a more reasonable ratio of the light used to the heat dissipated in the studio and furthermore, with the flexibility now given the lighting engineer, the overall lighting of the sets was beginning to show improvement. We were, however, still forced to introduce a film interlude or intermission between sequences to allow the personnel to readjust the lights, a complication that still limited the efforts of the programming staff and required considerable lighting personnel in the studio. We had the alternative, of course, of installing sufficient equipment overhead to illuminate each set individually, but such a

move was impracticable for several reasons. First of all, where a succession of sets is being used to shoot a television program it is generally necessary that these sets adjoin or overlap each other, so that the sets can be quickly and quietly shifted during the few seconds of the opening lines. Such an arrangement predicates a series of sets opening on a central shooting or camera area, and, of course, also predicates a common ceiling facing all sets. It would therefore be

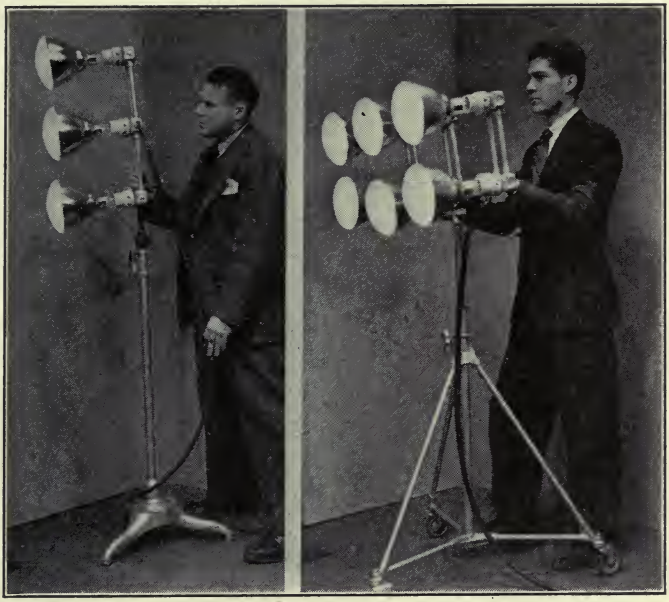

FIG. 5. The single-three unit.

FIG. 6. The floor broad.

impossible to install the equipment required by reason of these space limitations. In addition, although this particular studio had a specially reinforced ceiling designed to carry a reasonably heavy hanging load, a radical and major redesign would be required to carry the additional load of a duplicate lighting system. If further proof were needed that our one solution lay in increasing the flexibility of the present layout, it was found in the unavailability of the necessary power to energize new equipment.

We therefore designed and constructed an experimental "double-three" unit controllable in rotation, tilt, and elevation by means of a

series of ropes. This device was successfully tested in a studio program early in the summer of 1938 and because of its apparent possibilities for studio work, it was redesigned for production.

This "flexible double three" has become the basic unit of our remotely controlled lighting system. It consists of a standard fixture mounted on a hollow arm through which cables pass to rotate, tilt, and elevate the assembly. With a series of these remotely controlled units mounted overhead on the gridiron, their hemispheres of operation tangent to each other (Fig. 10), it is possible to select the particular lights available to any stage. The remaining units can then be reset remotely for the next sequence while the first group, when clear, can be brought into play on set three. This one-man control of the

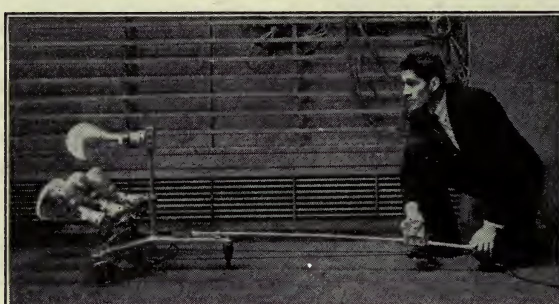

FIG. 7. Portable footlight.

overhead or foundation lighting appeared to be one logical answer to television's requirement for extreme flexibility. By operating the available fixtures an operator can readily establish a modeling angle, can control and shift the back lighting as the characters move about the stage, and also can preset the scene to be televised next. In addition, the lighting engineer is also given the opportunity to vary the lighting while action is taking place on the set to satisfy either technical or program requirements.

At the present time all control of these flexible units is accomplished by means of the four cables connecting each unit with the light-control bridge in the rear of the studio (Fig. 11). This is the control center of the entire lighting installation and as such merits a more complete description. The bridge platform is elevated ten feet above the floor and flanked on two sides with studio walls on which are arranged the fair-leads and cleats of the overhead array (Fig. 12).

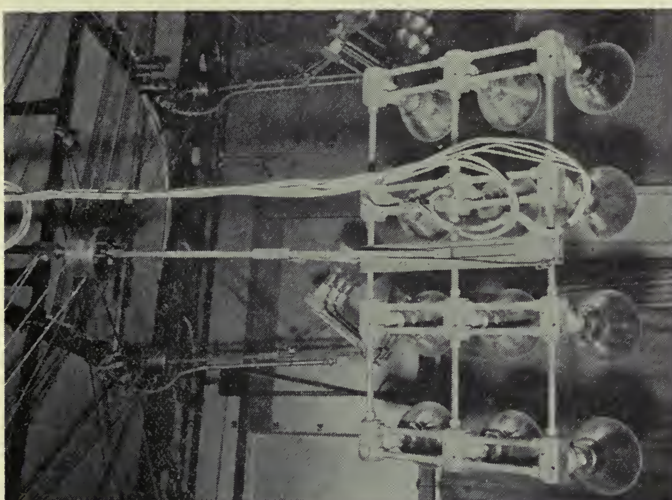

FIG. 8. Master modeling unit.

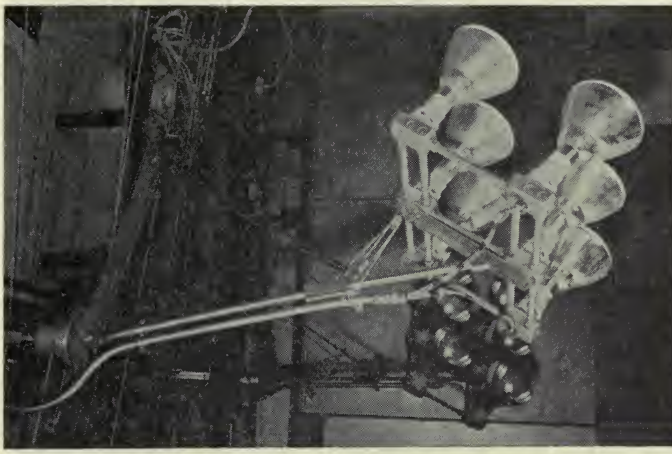

FIG. 9. Remotely controlled double-three unit.

FIG. 10. (*Upper*) Set of remotely controlled units, with hemispheres of operation tangent to each other.
FIG. 11. (*Lower*) Light-control bridge.

Along the open side of the bridge overlooking the studio floor is the pin-rail and access ladder. An electrical control board carries the silent mercury tumbler switches and the cross-over knife switches of the master modeling units. Two-way phone communication is provided between video control and the lighting engineer. But during a program this line is, of necessity, kept one way, light and hand signals being utilized in acknowledgments and in issuing instructions to the lighting technicians on the floor.

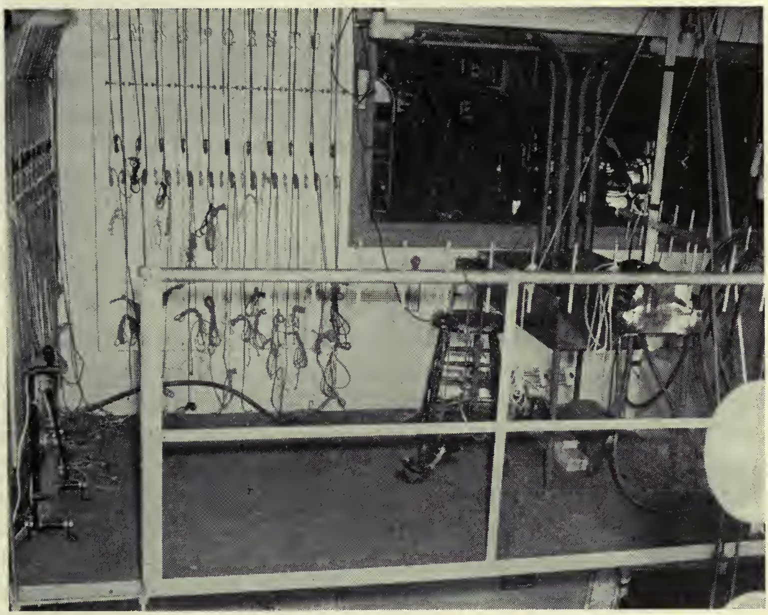

FIG. 12. Close-up of bridge, showing fair-leads and cleats of the overhead lighting array.

From the light-control bridge, the lighting engineer is able to view the entire studio. He can analyze the illumination on each stage and preset the succeeding stage while the action is going on in another part of the studio. Rearrangement of light can be and is continually varied to meet the requirements of the camera work. Movement of the two floor units is supervised and controlled by a system of hand signals, attention of the operator being attracted by flashing one of the units not in use.

With the full control of all the lights in the studio at his fingertips,

it is possible for the lighting engineer to create any reasonable lighting effect and illuminate any set satisfactorily for the television cameras. This, however, is nothing more than could be accomplished with a non-flexible system that had given way to the new installation. The test of this installation comes with the program utilizing a series of separated stages with little or no interval between sequences. In the cameras' operation, this requires only that one of the three cameras be withdrawn early enough in the closing sequence to be in position to open the new set. Audio can carry this change with a planted microphone for the opening lines until the boom can be swung around and faded in, but from the lighting angle such a change requires carefully timed maneuvering of the equipment to insure normal brilliance on the opening shot and no depreciation in light on the closing lines of the first set. In such a situation we make use of two suspended 6-kw broad units positioned at either end of the studio and controlled from the bridge separately from the other overhead array. These two units are termed master modeling units, from their normal use, but have proved invaluable in holding up the illumination during change of sets.

It is impossible, of course, to lay down set rules for shifting lights during a multi-set show. With the script before him and cognizant of the positions of the cameras on the floor, the engineer will first swing all the available unlighted units into position over the set coming up. By watching the camera operation, he can then begin to rob the outside units on the working set and swing them onto the next stage. If it is necessary to reduce the overhead array by an extreme amount, the operators on the floor units are instructed to move in to cover. The master modeling unit is next swung into position over the working set and one or more of the floor units are drawn back and redirected. Strip and ground row lighting has of course been planted during the early part of the sequence, so with the addition of the floor broads, the lighting can be considered normal and a verbal check is obtained from control on previewing the opening shot. As the action develops, more units from the first set can be brought over to reinforce this second set, the remainder being swung to the third stage and the procedure repeated.

Such a system of control necessitates only one and one-half to two times the equipment required to light a single set, but with proper manipulation any number of stages can be successively illuminated with similar installations.

In staging a variety show where the successive acts are rehearsed separately and no sequential plan of operation can be worked out, it is sometimes necessary to swing several banks of light simultaneously during the few seconds allotted to the Master of Ceremony's introduction. To do this, the units affected are tied off separately and the control lines equipped with preset rings. At the conclusion of the act, these presets are released from their hooks and the entire overhead system drops to its new position on the next stage.

To analyze our lighting installation, it is necessary to appreciate the difference between a television program and the shooting of a movie sequence. First, and of primary importance, is the fact that in television we have no editing privileges other than in the few seconds of preview obtained while focusing the opening camera. Second, our sets, of necessity, are adjacent to each other; and third, the restricted floor space must be kept clear for camera operation. This precludes any complication of floor-mounted equipment or extra personnel.

Because of the proximity of the sets, the ceiling space before the various stages is common to each, and as has already been pointed out, the lighting equipment placed overhead must be common to all. A flexible system such as ours appears to be one solution. The placing of all light-controls within the grasp of the lighting engineer allows him not only to exercise his own judgment in illuminating the sets, but in addition gives him an opportunity to correct an opening error without losing the entire sequence. This centralization of controls necessarily does away with the personnel required to handle the thirty-odd units that comprise the equipment. But by giving the engineer equipment that will satisfactorily produce a good television picture, and providing him with positive control of each unit wherever it may be positioned, it has, we believe, answered most of the present problems in television lighting.

To recapitulate, we have found that the remotely controlled foundation lighting possesses the required characteristics of extreme flexibility and high efficiency. The floor units are light, portable, and, where required, can be remotely controlled. The angle of overhead illumination can be adjusted and maintained for all conditions of set depth and length of throw. Backlight can be controlled remotely and can be made to follow the action on the stage. The problem of lighting successive stages can be handled either by splitting the available light or by following the action directly with one or more banks

of the remotely controlled lamps. Economically the system now in use is satisfactory. With standard long-life lamps the replacement cost is quite low. The personnel requirements have been substantially reduced. At the present time three operators can satisfactorily handle all the lighting equipment even though an hour's program may cover as many as ten different stages. The set-up time formerly required to readjust the studio lighting for a change in set location has been reduced from hours to minutes. Equipment has been simplified, reduced in size, or removed from the floor altogether, providing additional space for camera operation. With one standardized type of light it is possible to estimate quickly the quantity of light and its distribution on the set rather than having to interpolate the resultant light from several different sources.

Without attempting to give the impression that we have discovered the panacea of the lighting troubles in television, we do feel this installation is a reasonable solution to our present requirements. This installation is but another phase of our developmental work in television. It is, we believe, a step toward solution of the problems of large-scale television broadcasting.

REFERENCE

[1] EDDY, W. C.: "Television Lighting," *J. Soc. Mot. Pict. Eng.*, **XXXIII** (July, 1939), p. 41.

DISCUSSION

MR. KURLANDER: New York City has an ordinance requiring that the spotlight lenses be covered with wire netting.

MR. EDDY: This unit has been approved by the New York Board of Fire Underwriters for all conditions of operation and fire protection. The lamps use 300 watts apiece, making a total of $1^1/_2$ kw for the unit. With the 500-watt lamps, we use 3 kw. In two years of operation, during which we used something around 86 kw nearly every day and most of the night, nothing has ever happened to the lamps.

MR. KURLANDER: What is the average wattage on the set?

MR. EDDY: We think in terms of foot-candles. We can not consider any one set, because the lighting depends upon the subject matter and the way in which we feel it should be lighted. One type of scene will be in a lower key than another. We use from 400 to 1000 foot-candles, 1000 being the maximum.

MR. KURLANDER: The question of breakage is very serious. We have had some sad experiences with lamps that we thought were perfectly safe. When the filament of a gas-filled lamp operating at a high temperature fails in service, hot tungsten may drop on the bulb and create such severe glass strain that the bulb may explode. What protective measures have you for that?

MR. EDDY: All these lamps are given a very thorough high-voltage test before being put into use.

MR. KURLANDER: Does that mean that they will never burn out?

MR. EDDY: No. We flash them to be sure there are no weak stems or similar defects. If one leaks it is likely to burn out in the 140-volt d-c test. I do not say the lamps are infallible and I am not particularly emphasizing this type of lamp. We are primarily interested in answering the problem of lighting in a television studio. Any suitable type of lamp might be used. This is primarily a holder for an illumination device. We happened to use these lamps because they are efficient and are the lightest in weight that we could get.

DR. GOLDSMITH: You could surround them with gauze, if necessary?

MR. EDDY: They could be surrounded with gauze or wire. I have thought of doing so, but having no reason for it as yet I have not gone that far.

MR. KURLANDER: The weakest part is just above the base, where the glass is subjected to great heat. Very severe strains are sometimes created in the glass, and the whole bulb may come off.

MR. EDDY: In our early tests we expected something like that, and were very careful about putting the lamps close to a working set and lighting them with 120 volts d-c in a very cold studio at about 65°F. We thought surely the lamps would break when putting on the voltage without dimmers. But in two or three months of experimentation we lost no bulbs and have had no accidents.

MATHEMATICAL EXPRESSION OF DEVELOPER BEHAVIOR*

J. R. ALBURGER**

Summary.—*Characteristics of developing agents have been unified in a mathematical expression. The use of the analysis of developer behavior afforded by this expression has been helpful in providing a guide toward improving a developer with respect to any given characteristic.*

During experimentation with the "peptized sol" developer[1] it was observed that a curious effect was obtained when alkali concentration was raised sufficiently high. The effect was first noticed in Duratol (para-benzyl-amino-phenol). In a solution containing 0.2 to 0.5 per cent sodium hydroxide, normal development was obtained. When the concentration was raised to 2 or 3 per cent a surface development evidenced itself. It seemed that the developer was simply not penetrating to the lower levels of the emulsion. This observation started off a series of investigations to see what effects of a similar nature could be obtained with other agents and what the factors of control were. In the course of the work, a number of interesting facts were discovered, many of which have given us new insight into the chemistry of developers.

The importance of surface development may not seem immediately evident. There is, however, a reason for investigating this subject in detail. In the more or less classical Hurter and Driffield analysis of photographic physics, certain well defined laws are laid down. It seems that these laws change when certain conditions of concentrations in developer composition are used. According to the H&D analysis, presence of bromide in a developer shifts the intersection point of the extended straight-line portions of the characteristic curves down below the zero axis of density.

The result of shifting this intersection point down is that the gamma becomes less affected by development time. With a de-

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 20, 1940.

** RCA Manufacturing Co., Camden, N. J.

veloper containing bromide, toe densities are inhibited, and in order to get low contrast suitable for negative development, it is necessary to underdevelop the film. When this is done, emulsion speed is lost. The effect of bromide on a developer is shown in Fig. 1.

Under certain conditions, however, it is possible to move this point of intersection back up above the zero axis even though the potassium bromide concentration is above 10 grams per liter. This departure from the classical Hurter and Driffield theory led the writer

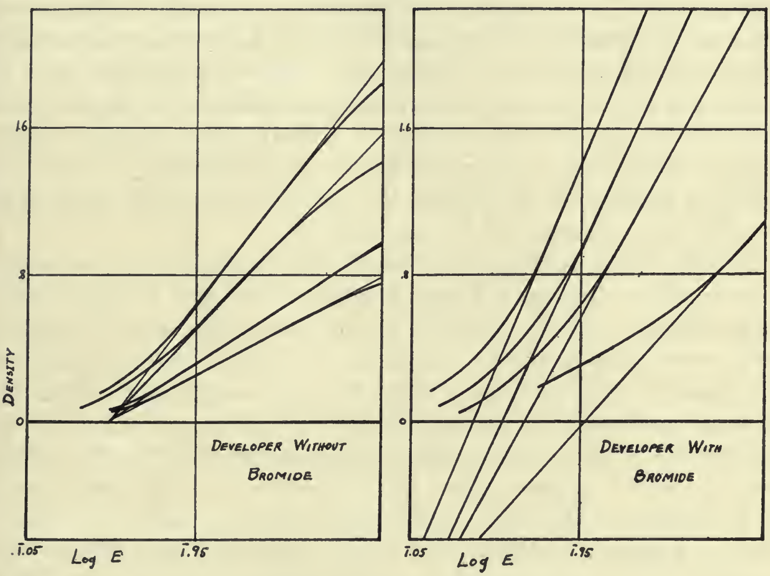

FIG. 1. Effect of bromide upon a developer.

to investigate the possibility that other extreme conditions might produce effects which would be useful.

THE PEPTIZED SOL AND POLYMERIZATION

An indication of a departure from the classical theory of developers evidenced itself when it became possible, through the use of the "polypeptized-sol" effect in buffering alkalinity to utilize extreme conditions in alkaline concentrations. By the addition of potassium alum to a solution of sodium hydroxide, a complex salt is formed which can be considered to be sodium aluminate. Strictly speaking,

the solution contains acid aluminate which is peptized on a few sodium aluminate molecules forming an agglomeration of molecules or a peptized group. All reactions in the solution exist in equilibrium, so that regardless of the concentration of alkali, there will be always a certain effect felt in the solution due to the potassium alum. The presence of the alum in a developer formula of this type serves two functions. First, it prevents swelling of the gelatin of the film even at temperatures as high as 110°F. Second, it serves to harden the developed image far beyond any point obtained even in an acid hardener fixing bath. For example, concentrations of sodium hydroxide as great as 200 grams per liter may be used in a developer at temperatures well above 100° as long as the solution is buffered with an amount of potassium alum equivalent to four-thirds the weight of the sodium hydroxide. This method of buffering the alkalinity of developer solutions so as to minimize the physical effects of the alkali makes it possible to investigate the properties of agents when used in solutions containing such concentrations.

As was stated before, the effect of surface development was first observed with the agent Duratol, which chemically is para-benzylaminophenol. It was observed in the case of this agent that solutions containing less than 10 grams per liter of sodium hydroxide developed normal contrast. When the concentration of sodium hydroxide was raised to between 20 and 30 grams per liter, the developed contrast was decreased. By examination of the film during development, it appeared that development was taking place mostly on the surface of the film. It was found that the greater the concentration of sodium hydroxide, the more pronounced this surface effect became. This particular surface effect will be referred to as "alkalinity surface effect." The appearance of this phenomenon aroused interest in the possibility that a similar effect might be obtained with other agents. Hydroquinone was tried and found to exhibit the surface effect starting at the concentration of about 60 grams per liter of sodium hydroxide. Glycine was tried and found to require about 110 grams per liter of sodium hydroxide before the surface effect evidenced itself.

An explanation for this surface effect was sought, a possibility being that the developer molecules were not penetrating into the depths of the emulsion. One conceivable mechanism would be that the "salt effect" of high concentrations of dissolved substances produces a physical effect on the gelatin to slow down the penetration of developer.

However, another possibility appeared that the developer molecules themselves might become peptized into groups of molecules under the influence of large concentrations of sodium hydroxide. The large group thus formed would be unable to penetrate rapidly into the gelatin of the film. Having considerable energy due to the high concentration of sodium hydroxide, development near the surface would proceed rapidly so that full emulsion speed would be obtained while the developed gamma was reduced.

It could be that the "salt effect" on the gelatin would evidence itself at less sodium hydroxide concentration on agents of high molecular weight. However, a number of facts observed in experiments indicate that the size of the developer molecule, while exerting a major influence, is not the only factor involved.

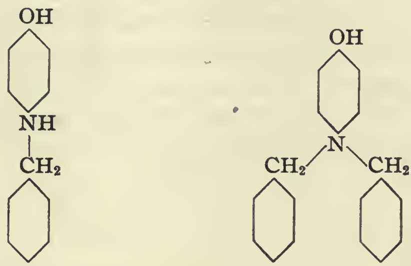

FIG. 2. (*Left*) Duratol (benzyl-*p*-aminophenol) and (*right*) dibenzyl-*p*-aminophenol.

It appears that the surface effect is a function of the sodium hydroxide concentration. The effect also seems relatively dependent on the structure of the compound. Experiment bears this out somewhat since para-benzyl-amino-phenol behaves normally in a weakly alkaline solution. When the sodium hydroxide concentration reaches about twenty grams per liter, surface development becomes apparent. In the case of glycin or hydroquinone, surface development is not obtained until a concentration of about 100 grams per liter is reached. The size of the developer molecule also should be expected to have a part in the surface effect.

It was reasoned that if this were true, we should be able to obtain a similar effect of surface development by starting out with a developer composed of large molecules. Inasmuch as very few developers were available which had sufficient molecular weight, it was necessary to

synthesize agents. The first synthesis was an additional substitution in Duratol. Duratol consists of para-aminophenol with a benzyl group ($C_6H_5.CH_2$) substituted in place of one of the hydrogen atoms in the amino radical (Fig. 2).

Para-dibenzyl-aminophenol is the same with the additional substitution of a benzyl group for the other hydrogen atom in the amino radical $CH.C_6H_4N(CH_2.C_6H_5)_2$. The compound thus formed has three benzene rings present in it as compared with two for the original Duratol. The molecular weight is slightly more than half again as great, and if the surface development were dependent on molecular size, we should expect a more pronounced effect from this agent. This was found to be true. The surface effect evidenced itself at a concentration of about 5 grams per liter of sodium hydroxide.

Several other syntheses were carried out, and the agents produced were investigated as to their properties in the matter of surface development. Substitution of groups containing benzene rings tended to reduce the solubility of the compound formed. Tetra-benzyl-para-amino aniline $[N.C_6H_4.N(CH_2.C_6H_5)_4]$ is almost completely insoluble even in very strong alkali (Fig. 3).

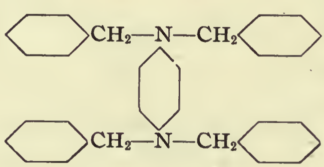

FIG. 3. Tetrabenzyl-*p*-aminoaniline.

However, what little of the material does go into the solution evidences an extremely pronounced surface effect. Full emulsion speed is obtained but the developed gamma is down below 0.2 or 0.1. The use of such a substance as a developer does not appear to be immediately worth while. However, a secondary effect arises which might conceivably be put to good use. After developing the original image in this developer, the film can be fully exposed to white light and redeveloped in ordinary developer, whereby the effect of reversal is obtained.

There are two other functions in developer behavior besides the alkalinity surface effect which are dependent on the alkalinity of the solution. First and most obvious is the alkalinity energy function. It is well known that amidol (2-4-diamino phenol) will develop in acid

solution. Other agents require greater alkalinity before they become energized. In general, the energy of a developer in very strong acid solution approaches zero. At a certain *p*H, the energy rises rapidly in $\tan^{-1}$ function and at high concentrations of alkali, approaches a maximum value. It seems necessary to consider two factors in the energy function of the developing agent; both, however, would be dependent to a certain degree on the reduction potential of the developing agent. In the one case, there is the question of the *p*H at which the developer energy rises at its maximum rate. The other factor is what is the maximum value of energy or fogging energy of the developer. For most ordinary developing agents, the energy begins to rise at a point very closely above neutrality of solution. The maximum value of the energy involves, additionally, a certain function of the oxidation potential of the emulsion.

The second effect, which heretofore has had only brief mention in any of the journals and publications, is what will be termed "acid surface effect." From time to time it has been mentioned that certain fine-grained developers which operate in near-neutral solution exhibit an effect of surface development. In certain cases, developed images are found to be of very low contrast due to this effect. The term "acid surface effect" is used for want of a better expression of the phenomenon in question. It has been suggested that the *alkaline* surface effect is caused either by a "salt effect" on the gelatin or by the grouping together of developer molecules to produce large groups of molecules which diffuse but slowly into the emulsion being developed. The *acid* surface effect may be considered to be caused by an effective exhaustion or decrease in energy of the developer during passage into the emulsion depths. Diminution of density due to partial development of the silver grains would be a contributing factor in the acid surface effect. Under conditions where the agent is not strongly energized by alkali, it may experience an effective exhaustion or slowing down of activity in the near neighborhood of a nucleus being developed. This would give much the same result, producing lowered contrast and a tendency toward fine grained images.

Thus, as the *p*H is varied, a condition is found which gives maximum image penetration and maximum contrast, and to either side of this *p*H value the image is confined more nearly to the emulsion surface and the contrast is diminished. If the low contrast is that corresponding to low *p*H, we have called it the "acid surface effect"

(because low pH is in the direction of acidity) even though the solution may still be on the alkaline side of neutral. During the study of these phenomena, every available developing agent was investigated and it appears that for all these developers there is what might be called an "acid surface effect" whereby the maximum effect is exhibited in strongly acid solution. As the alkalinity is increased, the point at which the acid surface effect falls off in a tangential function and approaches zero, differs for various agents. To be sure, in a strongly acid solution the developer energy is very low, tending to

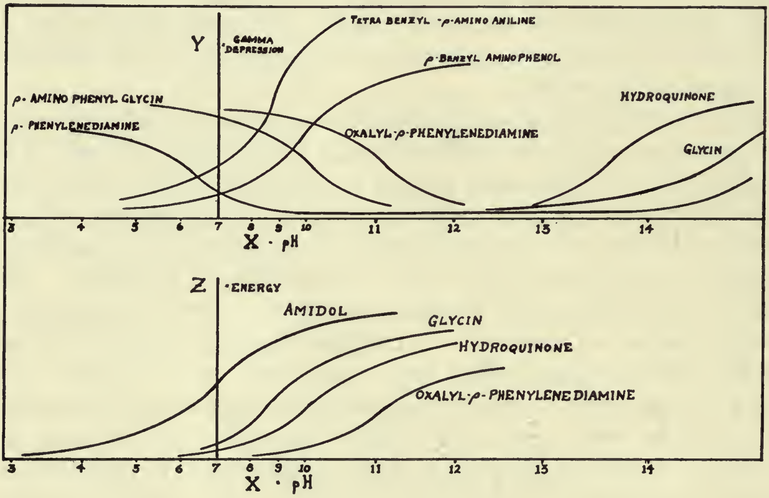

FIG. 4. Characteristic curves for several developing agents.

mask any acid surface effect which might be present in the developer. For example, hydroquinone is almost completely inactive in acid solution. There are cases, however, which exhibit this acid surface effect even in strongly alkaline solution. A good example of this is oxalyl-paraphenylenediamine. This material exhibits an acid surface effect up to a concentration of about 10 grams per liter of sodium hydroxide. At these concentrations, the alkalinity energy is sufficiently great to allow convenient observation of the effect. When about 15 grams per liter of sodium hydroxide is used with this agent the acid surface effect diminishes rapidly, and normal development takes place at a concentration of between 25 and 30 grams of sodium

hydroxide per liter. Unfortunately, this compound is unstable and hydrolyzes in water solution.

The point at which this acid surface effect falls off seems to be dependent partly on the reduction potential. Thus a substance which evidences pronounced acid surface effect can be expected to have a low reduction potential, although this is not always the case. There are other factors which have bearing on this function, such as the various possible substitutions into the composition of the developing agent.

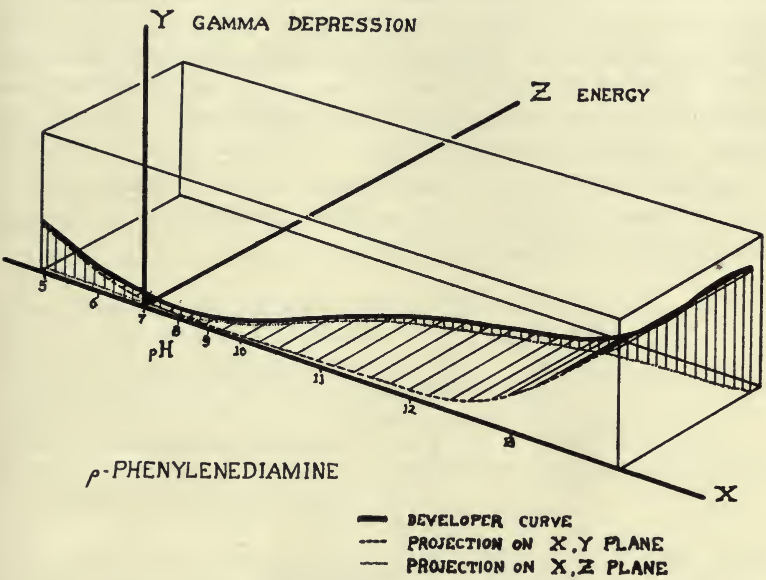

FIG. 5. Three-dimensional representation of Fig. 4.

Fig. 4 shows representative characteristic curves for several developing agents. Note that the curve of gamma depression for *p*-phenylenediamine has a rise at both ends. A three-dimensional construction of the curve of developer behavior is illustrated in Fig. 5. The curves shown in Fig. 4 are the projections of the developer curve on the x, y and x, z planes, respectively. Fig. 5 is another way of showing the relationship indicated in Fig. 4.

It will be noted that the surface effect is not expressed by any definite numerical quantities. At best, only an arbitrary standard could be fixed upon, and the values of the constants in the equations would depend on the choice of this standard. The shape of the curves

turns out to be such that they can be expressed approximately by equations of the form shown below.

Strictly speaking, we have two equations because the curved line which represents developer behavior lies in three dimensions; that is, we are plotting developer energy against alkalinity in one plane, and combining that with a relationship between alkalinity and surface effect. The surface effect in the final equation is an addition of the acid surface effect and the alkalinity surface effect. It appears from the behavior of the agents studied that the various functions take a tangential or, if one wishes, a $\tan^{-1}$ form. It does not appear likely that there would be any appreciable error arising from this assumption.

The shape of the tangential curves may be varied by choice of suitable constants; that is, the curves may be either widened, elongated, or shifted to the right or left.

The following three equations express in most general terms the three functions: alkalinity surface effect, alkalinity energy, and acid surface effect, all as functions of pH.

$$X - a - b \tan \frac{1}{c}\left(y - \frac{\pi c}{2}\right) = 0 \qquad \text{Alkalinity Surface Effect} \qquad (1)$$

$$X - d - e \tan \frac{1}{f}\left(Z - \frac{\pi f}{2}\right) = 0 \qquad \text{Akalinity Energy} \qquad (2)$$

$$-X - g - h \tan \frac{1}{i}\left(y' - \frac{\pi i}{2}\right) = 0 \qquad \text{Acid Surface Effect} \qquad (3)$$

$$\text{from } 1,\ \tan \frac{1}{c}\left(y - \frac{\pi}{2} c\right) = \frac{X - a}{b}$$

$$\frac{1}{c}\left(y - \frac{\pi c}{2}\right) = \tan^{-1} \frac{X - a}{b}$$

$$y = c \tan^{-1} \frac{X - a}{b} + \frac{\pi c}{2}$$

$$\text{from } 3,\ y = i \tan^{-1} \frac{-X - g}{h} + \frac{\pi i}{2}$$

Curve which is summation along Y ordinate

$$Y = y + y' = c \tan^{-1} \frac{X - a}{b} + i \tan^{-1} \frac{-X - g}{h} + \frac{\pi c}{2} + \frac{\pi i}{2}$$

$$Z = f \tan^{-1} \frac{X - d}{e} + \frac{\pi f}{2}\ '$$

Y = Surface effect (gamma depression)
Z = Developer energy
X = pH of the solution or NaOH concentration

Increasing *a* shifts curve to right	(X, Y Plane)	Right Rise Alk.-Surface
Increasing *b* elongates curve	(X, Y Plane)	
Increasing *c* widens curve	(X, Y Plane)	
Increasing *d* shifts curve to right	(X, Z Plane)	Alk. Energy
Increasing *e* elongates curve	(X, Z Plane)	
Increasing *f* widens curve	(X, Z Plane)	
Increasing *g* shifts curve to left	(X, Y Plane)	Left Rise Acid Surface
Increasing *h* elongates curve	(X, Y Plane)	
Increasing *i* widens curve	(X, Y Plane)	

To make use of these equations, it was found expedient to enumerate a number of factors which have a bearing on the characteristics of a given developing agent. In this way a picture is afforded of developer behavior which allows more satisfactory choice of agents for a desired result.

Dependents

a Linkage factor depending on type of linkage groups
b
c Molecular size (no. of benzene rings)
d Inverse reduction potential function
e Reduction potential function
f Oxidation potential and reduction potential
g Reduction potential function, also basic groups in molecule
h Acidic groups present in molecule
i Type of reaction products which inhibit development; also reduction potential variations which affect grain size

The dependents enumerated here are merely a rough indication of the influences bearing on the behavior of a developing agent. By observation of the effect of substitution of certain groups in the developer molecule, it has become possible to predict the characteristics of an agent in respect to surface effect and grain structure.

For a picture negative developer, fine grain is desired. Observation shows that if an agent is used in such a way that the operation is carried out on the *acid surface* characteristic, minmum grain size will be obtained. Full emulsion speed is desired and sufficient energy to overcome bromide effect. Thus we find it necessary to work on the high end of the *alkalinity energy* curve. The operating *p*H should also be considered due to the effect of *p*H on emulsion turbidity, swelling of the gelatin, and aerial oxidation. Accordingly it is possible to choose agents which have the necessary characteristics

for picture negative development or for variable-density sound negative development.

In carrying through these investigations a radical departure from accepted photographic practice was found practicable and even necessary. First, it has been generally believed that the presence of bromide in a picture negative developer was very undesirable inasmuch as emulsion speed would be diminished. However, by suitable choice of developing agents and operating conditions, it has been found possible to retain complete emulsion speed and shadow detail even with 10 grams per liter of bromide in solution.

A second belief which has held sway is the idea that emulsion speed will be lost if grain size is diminished. Under certain circumstances this has been found to be decidedly not the case. Extremely fine grain similar to that obtained in a *p*-phenylenediamine-sulfite developer has been obtained with emulsion speed and shadow detail equal to a high-energy *M-Q* developer.

A third widely accepted idea is that fine-grain development is impossible in strongly alkaline solution. Some of the experimental formulas tested contained as much as forty grams per liter of sodium hydroxide, which seems to be rather extreme alkalinity. However, fine grain was obtained with full emulsion speed and complete shadow detail. Unfortunately, with many thick negative emulsions, increased turbidity very often causes loss of detail even though the grain is fine.

There are a number of considerations to be noted in the design of a picture negative or variable-density sound negative developer. Briefly, they are:

(*1*) Fine grain
(*2*) High resolving power
(*3*) Correct H&D characteristic for the purpose to which the developer is to be put
(*4*) Complete emulsion speed and shadow detail
(*5*) Freedom from bromide inhibition
(*6*) Minimum tendency toward oxidation by air

The fact that developer characteristics may be unified in a mathematical expression has been extremely interesting, but the matter of prime importance is the fact that by use of the analysis of developer behavior afforded by these expressions, there has been provided a guide toward improving a developer with respect to any given characteristic.

REFERENCE

[1] ALBURGER, J. R.: "RCA Aluminate Developers," *J. Soc. Mot. Pict. Eng.*, **XXXIII** (Sept., 1939), p. 296.

DISCUSSION

MR. CRABTREE: Have you tried adding an inert substance, such as sodium sulfate, to the developer? It is well known that inert substances, such as sodium sulfate or magnesium sulfate, glucose, sugar, and so on, not only retard development but produce a decided surface effect.

When potassium alum is neutralized with caustic soda, approximately the same weight of sodium sulfate is formed as the caustic soda used. I understand that quantities of caustic soda, of the order of 200 grams per liter, were used, which would produce 200 grams per liter of sodium sulfate, which in turn would produce a decided surface effect.

MR. ALBURGER: That is true, and there is a certain relation between the two functions. However, the salting-out effect does not seem to be the entire story. As was mentioned about the *p*-benzyl amino phenol, the surface effect became evident at 5 grams per liter of sodium hydroxide.

MR. CRABTREE: What was the *p*H of the solution in the presence of 200 grams of sodium hydroxide?

MR. ALBURGER: It could not be measured, because our meter goes only to 14, and we would have had to guess from there on.

MR. EVANS: Do I understand that in this series of sodium hydroxide you maintained the alum ratio at four-thirds throughout the series?

MR. ALBURGER: Yes. In all of this series we measured the concentration of sodium hydroxide, and each concentration was suitably balanced with four-thirds of the weight of potassium alum.

MR. EVANS: The final equation you plot is a characteristic of such a series of aluminate concentrations?

MR. ALBURGER: Yes.

MR. EVANS: I take it that you are not proposing to extend your conclusions to the developing agent, as such, but just state it for such a series of solutions?

MR. ALBURGER: At this time, yes.

MR. CRABTREE: Did you encounter difficulty due to precipitation of alumina in the fixing bath?

MR. ALBURGER: We encountered no trouble in that respect. It was thought for a while that we might have considerable trouble, but tests were made, and the only effect was more rapid deterioration. In other words, it would neutralize the acid in the fixing bath more quickly than an ordinary developer would.

A MODERN STUDIO LABORATORY*

G. M. BEST AND F. R. GAGE**

Summary.—*A description of the new laboratory erected by Warner Bros. at Burbank, Calif., in 1938. No general release work is required of this laboratory, and the generous space provided is devoted exclusively to the developing and printing of the dailies, storage and handling of the negative, and the latest in air-conditioning and dust-removing equipment. Advantage has been taken of the recent developments in rust-resisting and acid-proof metals, especially in the construction of the developing machine tanks. The description includes the method of operation through the dailies, negative cutting, printing, chemical mixing, silver recovery, and other essential processes.*

In the spring of 1938, Warner Bros. completed a new laboratory on a site adjacent to their Burbank lot, replacing their Hollywood laboratory which had served the studio for the previous fifteen years.

The new laboratory differs from most of the West Coast laboratories in that it is designed for handling only the film involved in preparing pictures for release. All release work, except for three prints made for the Los Angeles area, is done by the Ace Film Laboratories in Brooklyn, N. Y. Therefore the primary functions of the new laboratory are not release problems, but are confined to developing the negative, printing the dailies therefrom, reprinting at a later date the tracks used for dubbing, cutting the negative, and finally the preparation of the first answer, or preview composite print. In addition, all composite duplicate negatives and master prints for foreign release are made on equipment especially designed for the purpose and not used for any other work.

The main building of the new laboratory is shown in Fig. 1. It has been laid out with ample room for all departments, no function of the laboratory processes being impaired due to lack of space. Built entirely of reinforced concrete, the building was engineered to provide for future expansion, there being unoccupied space available on the

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 20, 1940.

** Warner Bros. Pictures, Inc., Burbank, Calif.

second floor and an additional story can be built in the future without modifications to the existing building walls. All windows are of glass brick, being in the form of a continuous section, making available a maximum of illumination in those departments which can work in daylight. Modern air-conditioning has made possible the use of this type of window to especial advantage in a plant which must be kept free from dust.

Although there are a number of emergency fire exits, only three doors are ordinarily used, and traffic is limited to two of the doors

FIG. 1. Exterior of main building.

during a normal day's work. This minimizes the difficulty due to tracking in of dust on the feet of employees, as both doors open into halls far from the printing and developing section. The greatest enemy of a motion picture laboratory is dust and every precaution for its elimination has been taken in the design of the building.

The first floor plan is shown in Fig. 2, all departments except the projection rooms and the chemical mixing and storage being on this floor. The developing equipment occupies about forty per cent of the first floor space and consists of six machines designed and built by Warner Bros. The machines are built in pairs, each set of developing and fixing tanks being located in a separate room, with exits into

the hallways at each end. The main wash tanks and dryboxes are in a common room finished in white enamel and illuminated on two sides by glass-brick windows, this room being connected to the developing rooms by a light-trap, the only one in the building.

The first machine group is set aside for positive prints only, and is located directly opposite the door leading into the printing room, enabling the delivery of prints from the latter with a minimum of

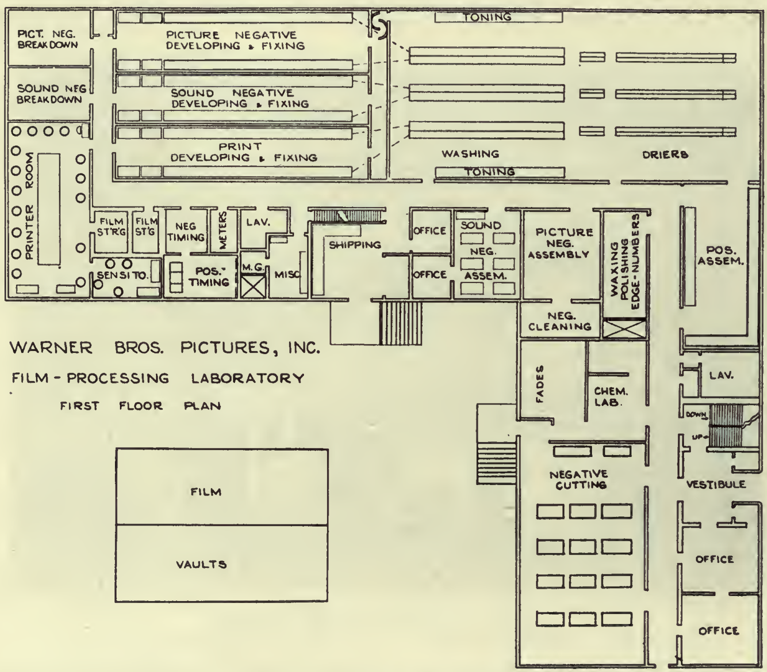

Fig. 2. First floor plan.

delay. The second group consists of a machine for sound-track negative, with additional tanks which can be cut in if the machine is to be used for emergency positive developing. Another machine in the same room develops process keys and special work, with two sets of developing tanks as in the sound-track machine.

The third machine group includes a machine for picture negative only, and the other is used for fine-grain duplicate negatives for foreign release. All doors leading into the developing machine rooms are permanently open, as the hallway is painted black and lighted

with green safelights, the first white light being in the hall around the corner, far enough away from the picture negative machine that it will not fog the fastest types of panchromatic film. The absence of light-traps in the hallway facilitates the plant operation to a remarkable degree.

The printing room equipment for picture consists of eight Bell & Howell Model *D* printers, of which three have automatic light-changing panels and the remainder are hand-set. The sound printers which are shown in Fig. 3, consist of a group of four machines built

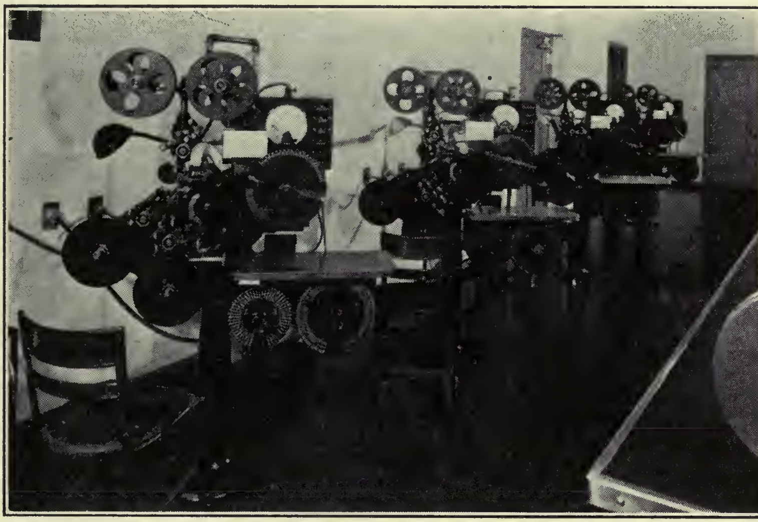

FIG. 3. Sound-track printers.

by A. J. Tondreau, head of the Camera and Laboratory Repair Department of the studio, during the past year, replacing a like number of modified Bell & Howell Model *D* printers. The new printers have been designed to print any type of sound-track required by the studio, although their principal work is ultraviolet variable-area. Arrangements for variable-density printing are included, together with filters and aperture changers for fine-grain duplicating master positives or fine-grain duplicate negatives, all at a standard speed of seventy-two feet per minute. Previous printers used for fine-grain work required slow speeds in order to have sufficient exposure, but

the development of a new type vacuum cooling chamber to house the printing light has made possible the use of Mazda lamps of sufficient intensity that these printers may operate at their standard speeds at all times for any type of work.

In a small annex off the printing room are two Eastman Model II*b* sensitometers for turning out negative and positive strips for processing control; also a Duplex printer for registration prints and two Bell & Howell Model *D* picture printers equipped with vacuum-cooled high-intensity lamps for fine-grain picture printing. A modified Bell & Howell Model *D* printer is retained in this room for emergency printing of fine-grain sound master prints which will fog in the normal type positive safelight illumination, but by closing the door into the main printing room, fine-grain printing can be done without holding up the routine of the main printing room.

The raw print stock is stored in a vault 900,000 square-feet in capacity adjacent to the printing room, and in the outside hall is another vault of 650,000 square-feet called the "Overnight" vault, in which developed negatives are stored when the night shift goes home. Directly opposite the second group of developing machines is the the sound-track breakdown room, where all sound-track dailies are brought from the studio and the "NG" and "HOLD" takes broken out of the rolls, only the "Choice" takes being processed.

Across from the third developing machine group is the picture negative breakdown room where all timing tests are broken out of the rolls before development. The "Test" system is used for picture timing, each "Choice" take having a short section of test exposure at the end. These tests are developed at normal time and inspected over opal glass inspection tables in the timing room. Changes in time of development are indicated by the timer and the work is processed accordingly.

At the turn of the hall, next to the drybox, is the positive assembly room. Here all prints are delivered from the take-up reels at the ends of the developing units and are mounted on reels if they are composite prints; or are synchronized, if separate sound-track and picture. Moviola equipment is used to synchronize scenes where there is difficulty in locating the start marks. In a room opposite the positive assembly are the polishing, waxing, and edge-numbering machines. Here the prints are waxed by the cold wax process and sent upstairs to the projection rooms, to be run at a standard speed of 90 feet per minute. There are no high-speed projectors, since no

release printing is involved and normal studio routine does not require it.

The negative assembly room for pictures is equipped with stainless steel, linoleum-topped tables at which the negative is inspected and the choice takes removed and spliced into rolls for printing. In back of the negative room is the negative cleaning room, equipped with a revolving velvet-covered drum having a capacity of 1000 feet of negative. All negative after being cut and spliced is thoroughly cleaned and dusted. No traffic into the room other than the two men employed there is permitted, and the incoming air is filtered through special dust filters.

Next to this group is the sound track-negative assembly room, where all sound-track is prepared for printing. Densitometer equipment for reading track densities, sensitometer strips, and negative fog density are installed, and all processing control for both picture and sound by sensitometry is determined at this point.

In sequence down the hall are the shipping room, motor-generator room, humidity and temperature control boards, and the timing rooms. The negative timing room has twin inspection glass frames for the negative test strips, while the positive timing is done with a twin projector assembly which projects two Cinex strips simultaneously, a frame at a time, permitting the comparison of the print to be timed with one of previously known characteristics. These projectors have liquid and air-cooled light-sources, eliminating the danger of fire.

In the wing of the building beyond the positive assembly room are the laboratory offices and the negative cutting room. In the latter the picture and sound-track negatives are matched to the cutting prints and the master negatives are prepared for release. The room has 21 linoleum-topped steel tables so that several pictures can be in work at one time. Before the cutting prints are allowed in the negative cutting room, they are thoroughly dry-cleaned in an annex where a continuous type cleaning machine using a non-inflammable solvent is installed. Cutting prints are invariably covered with oil, grease pencil marks, and dirt, the cleaning process stripping off all foreign matter without manual aid.

Next door is the chemical laboratory where the chemists run continuous tests on all solutions. Adjacent to the chemical laboratory is a room where chemical fades are made.

On the second floor are two large projection rooms having a throw

of 56 feet each, with a 16-foot picture. Here all synchronized dailies and composite prints are run at standard speed. Projection of fine-grain unwaxed master prints for foreign release is handled in a third projection room located in the laboratory machine shop adjacent to the main building, where the projectors are equipped with felt shoes to prevent damage to the unwaxed film.

The remainder of the upstairs floor space consists of unfinished rooms available for expansion. These rooms have been provided with adequate duct connections for all power, air-conditioning, vacuum, compressed air, and water which might be needed for any special processing that will be required in the future.

In the basement, in the section underneath the printing and breakdown rooms, is the chemical mixing and developer storage section. Three 1200-gallon and four 850-gallon tanks for developer storage are installed there, with a raised platform walk surrounding the tanks to facilitate inspection of the contents. Eight developer mixing tanks of 250 gallons each, of stainless steel, with motor-driven agitators, are located on the platform next to the storage tanks. Stainless steel piping connects the mixing tanks with the storage tanks, from which the developer is pumped to the machines through centrifugal pumps. All developing baths are filtered through filters made by the Commercial Filters Corp., using their cotton filter cells.

In a specially isolated room, the walls of which are treated to prevent acid decomposition, are the hypo storage tanks and silver recovery plant. Next door is the boiler room in which two automatic 75-hp gas or oil-fired boilers furnish heat for the air-conditioning plant. In the space underneath the office wing of the building are the air-conditioning equipment, emergency power plant, vacuum and air supply units, and the power switchboard. Ample space for storage of empty film cans and reels and laboratory supplies, a necessary evil in all laboratories, is located at the extreme end of the wing.

Outside the main building are the negative storage vaults (Fig. 4), in a building of reinforced concrete consisting of two stories, each floor having 12 vaults with a capacity of 1386 cans each, or a total possible footage capacity of about thirty-three million feet. Each vault is equipped with explosion vents and automatic sprinklers.

The laboratory machine shop is combined with the camera repair section and occupies a large building which completes the laboratory group. This shop is equipped for any kind of light or heavy repairs to the laboratory and is operated under the direction of Mr. A. J.

Tondreau. Here all printing machines and other units are periodically overhauled and serviced, this work being done without interruption to the laboratory routine.

In this shop the developing machines were fabricated. They are of the deep-tank, variable-elevator type, being improved designs of the same machines that have been in use for some years at the Ace Film Laboratories in Brooklyn and the old Warner Hollywood laboratory. The developer tanks are of stainless steel, 8 inches wide, 60 inches long, and 10 feet deep, the individual tanks being divided

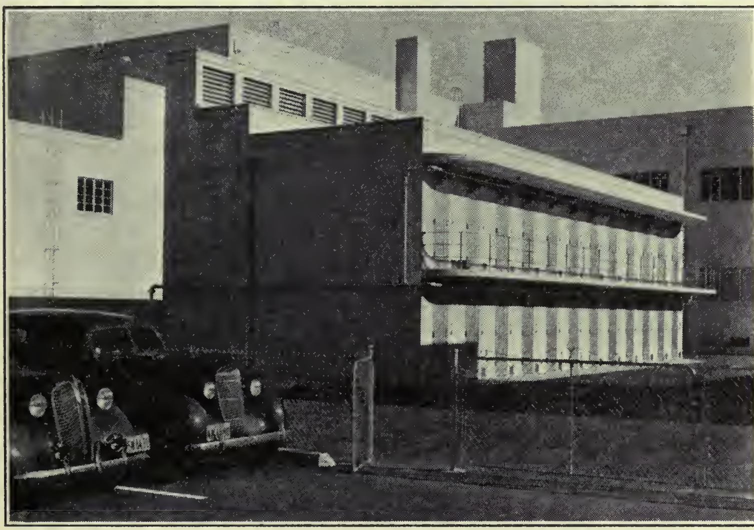

FIG. 4. Negative storage vaults.

in two sections called elevator sections. All rollers are of bakelite, there being eight sets to each elevator, with a total of nine loops of film. The lower set of rollers can be raised or lowered to shorten or lengthen the loops, thus permitting a fine adjustment of developing time without changing the speed of the film through the developer. At the end of each elevator there is a stainless steel driving sprocket, with a hard rubber friction roller for edge-guiding. The film remains totally immersed in the solution throughout development except when passing from one tank to another, reducing to a minimum the troubles from contact with the air during development.

Normal operating speed is 105 feet per minute, but the speed can be increased to 160 feet per minute through change in the driving-shaft speed made available by a gear transmission located next to

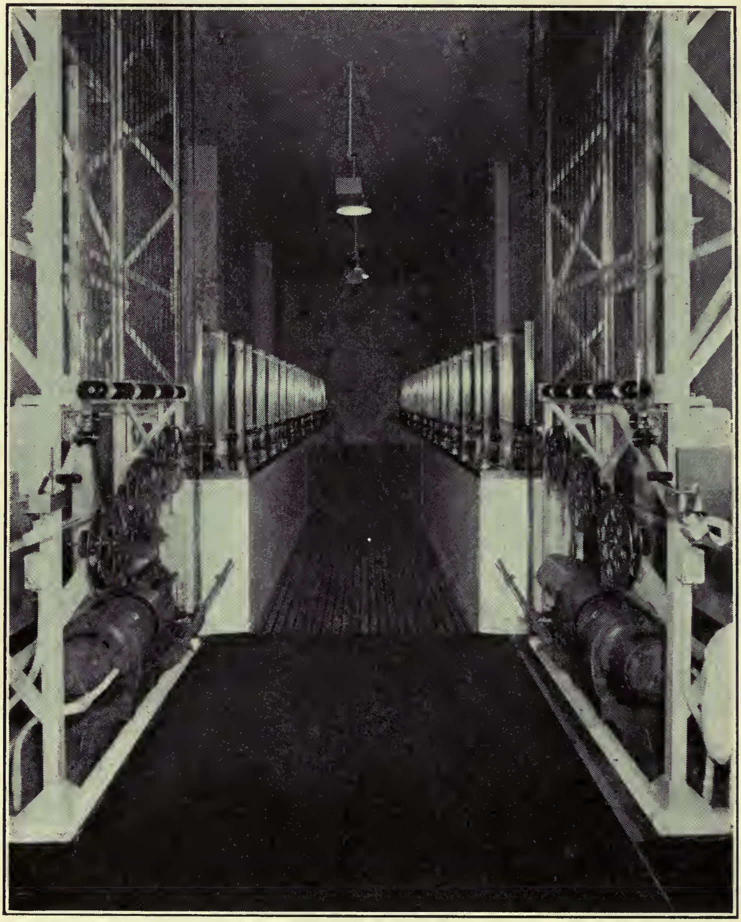

FIG. 5. Developing machine group.

the driving motor. This can be seen in Fig. 5, showing two of the developing machines looking from the input end. The film-storage rack at the input has a capacity of 400 feet, allowing ample time for the operator to splice the individual rolls.

The hypo tanks are of wood, the same size as the developer tanks, and at the end of the assembly is a rinse tank which removes a large portion of the hypo before the film passes through the wall into the washing and drying room. An air squeegee prevents water from dripping off the film during its air transit. The entire developer-hypo section of the machine is 46 feet long and is mounted on concrete pedestals which are set in the basement floor. The bottoms of all tanks are 6 feet above the floor, permitting free access underneath all tanks for inspection and plumbing repairs. The tops of the tanks stand three feet above the main floor, so that inspection and adjustment of the equipment is facilitated.

Each tank compartment contains a light-weight elevator bar on which are mounted eight spools held in place by a channel frame of stainless steel which permits complete removal of the film and roller assembly for cleaning purposes. This operation is performed manually since the entire unit weighs only 30 pounds.

All developing, fixing, and washing tanks have force-feed circulation of the solutions at 15 lbs. of pressure, the liquid being expelled from jets in the sides of eight vertically mounted, stainless steel pipes placed opposite each strand of film. It was found necessary to manufacture all stainless steel parts for the entire machine from the same type of steel, to avoid ruinous electrolysis. All fabricated steel was supplied by the A. J. Byer Co. of Los Angeles while the castings were made by the Electric Foundry Co. of Portland, Ore.

The normal developing time for picture negative is $7^1/_2$ minutes at 66°F., it being possible to vary the developing time from $5^1/_2$ to $11^1/_2$ minutes by loop-length changes without varying the speed of the film through the machine. Longer development is possible by slowing the speed of the drive shaft but has not been found necessary in practice. The picture negative developer is a modified form of Eastman *D-76*, maintained at a *p*H of about 8.70. At normal development time, a gamma of 0.65 is averaged on Eastman Plus *X* film.

For sound-track negative, a high-contrast metol-hydroquinone developer with a carbonate accelerator is used, the *p*H being kept at about 10.00; and for a gamma of 2.45 the film fog is kept at 0.05 for a developing time of 5 minutes. No variable-density negative is processed at the present time, but occasional density prints are made.

Positive development time of four minutes in a modified Eastman *D-16* developer at 66°F produces a gamma of 2.20 which is the aver-

age for all prints. The *p*H is maintained at about 10.15. Developer temperatures are kept constant to within 0.1°F by temperature controls made by the Brown Instrument Co., all solution temperatures being continuously recorded on Brown recorders, including humidity and temperature of drybox air. Processing conditions are checked by sensitometer strips, all types of development being under rigid sensitometric control.

The hypo circulating system starts at the central storage tank in the basement and branches to all developing machines through stainless

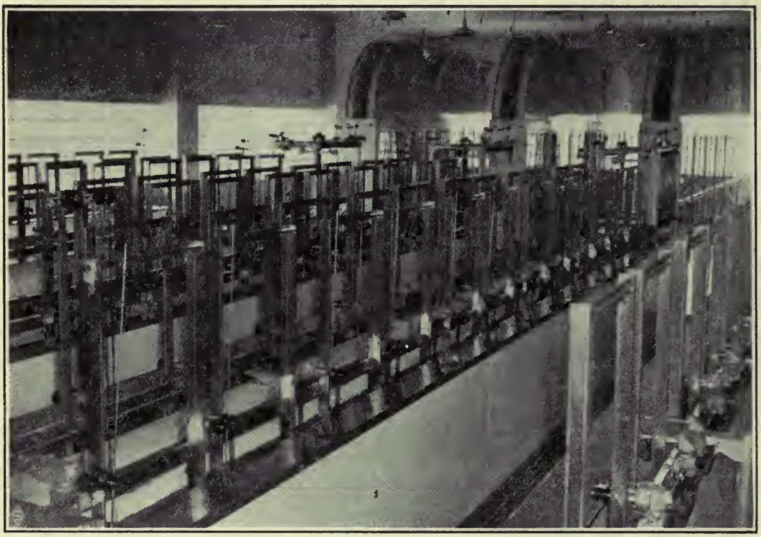

FIG. 6. Washing and drying equipment.

steel pipes. A common return line delivers the hypo to the silver-recovery system, where the pure metallic silver is electroplated onto stainless steel stripping plates. The plating operation requires a supply of 105 amperes at 2 volts, the current supply being a Rectox rectifier. Continuous agitation of the hypo in the plating tank prevents conversion of the silver to silver sulfide, the current-density per square-foot of plating surface being about 1.0 ampere at 2 volts. All hypo mixing is done in the same room with the hypo storage tanks, thus isolating all work on the fixing baths from the developer solutions.

Film washing is done in six tanks of two sections each, for each machine, these tanks being identical in design with the fixing tanks, including the pressure circulating system. Fig. 6 shows a general view of the wash room, with the roller frames partially elevated for cleaning. The normal time of washing is 18 minutes at 105 feet per minute. The water enters the two tanks closest to the drybox end, overflows to a pump, and is pumped to the next two tanks, where it

FIG. 7. Drybox terminal.

again overflows and is again pumped to the last two tanks, where it overflows to the sewer. By this arrangement, the amount of water used has been reduced by two-thirds as compared with the old plant. The exterior finish of the wash tanks is white enamel with stainless steel tops and trimming.

The dryboxes are built in three sections, as shown in Fig. 7, the air being kept at a uniform temperature of 75°F dry-bulb. Each drybox unit contains a dehumidifier, fan assembly, and filter system. The air is constantly recirculated, the water being extracted and the air returned again to the drybox intake, assuring a dust-free air sup-

ply at all times. Fig. 8 shows the air circulation fans and filter groups in the basement underneath the drybox units.

The three sections of each developing machine are operated by separate power drives, and between each unit is a safety storage rack having a maximum capacity of 11 minutes running time, allowing any section of the machine to be stopped. These storage racks are normally set for 100 feet of storage. The total length of

Fig. 8. Basement drybox construction.

film in the negative machines is 5500 feet, so that about 52 minutes is required from the time the raw exposed stock is fed into the input, until it is wound up on the drybox terminal. The positive threading length is about a thousand feet shorter due to less footage required in the processing, with a total running time of 42 minutes. All controls are operated from the end of the dryboxes, with telephone and alarm signals connecting the inputs and outputs of the machines. Automatic trip signals indicate when the safety storage racks between the units are approaching their empty or full condition, giving ample warning to the operators.

On each side of the main wash-tank group is a set of tanks used for toning, reducing, or intensifying. With the present trend of sepia toning on many pictures, these tanks have proved very useful in handling such work.

The system used for maintaining solution temperatures as well as for air-conditioning is a combination of artesian well water supply and artificial refrigeration. One well, adjacent to the building, sunk to a depth of 185 feet, supplies from 500 to 900 gallons per minute at 66°F through a 30-hp pump. This temperature does not vary more than $^1/_2$° throughout the year, and is used for precooling in the summer and preheating in the winter, through coils located in the incoming air-stream.

As an example of operation, assume an outside air temperature of 100°F, passing over a precooling coil carrying this 66° well water. The air delivered out of the coil system will be approximately 77°, or a temperature drop of about 23°, with a cost only of operating a small pump. The remaining temperature drop of the air is accomplished in a second coil surface carrying chilled water, from the central storage system on which the Freon compressors are working, this drop amounting to about 10°. From this it will be seen that the mechanical refrigeration plant is handling only about one-third of the total temperature drop, with the well water carrying the balance.

The central plant consists of four compressors, two evaporators, two condensers (cooled with well water), and a storage tank. This unit's sole function is making chilled water, which is in turn pumped through the building to the various coils and exchangers for conditioning of the building and the control of developer temperatures.

The use of a number of small unit compressors rather than one or two large ones permits a new high in economical operation, in that the compressors come into operation in sequence, adding capacity in direct ratio to the load demand. These compressors operate in parallel in one common system, as do the condensers, and being entirely automatic, hand valves are eliminated regardless of the number of compressors in operation. As the chilled water demand is satisfied the compressors cut off in sequence, to a point where all are out of service. During an unprecedented heat wave in September, 1939, only two of the compressors operated continuously, with a third compressor cutting in for 10 minutes out of each hour. The fourth compressor was never required at any time. Servicing of compres-

sors, condensers, or other units of the system can be done without any danger of interruption to the plant. The use of small machines of 25 tons each effects further saving in operation because of lower demand of power as shown by the demand meter. Should there be a power failure for even a prolonged period, the machines are arranged to return to service in sequence, on the restoration of power, through a time-delay relay, preventing the full load of the machines from coming on the line simultaneously.

The air-conditioning system maintains a temperature of 74°F dry-bulb with $^1/_2$° accuracy, and a humidity control of $1^1/_2$ per cent at

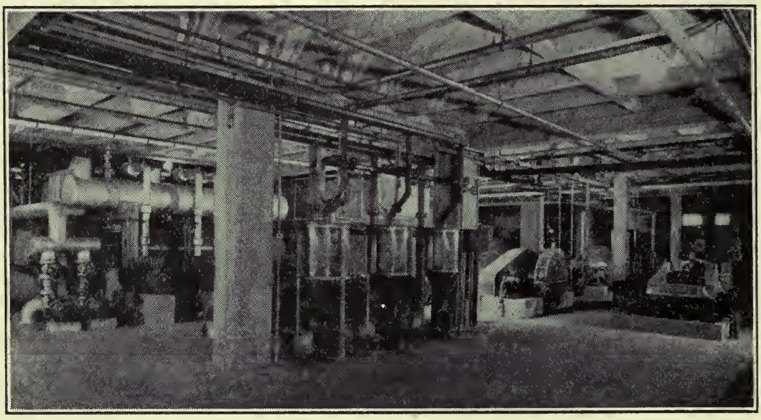

FIG. 9. Air-conditioning and emergency power plant.

55 per cent relative humidity. All air-conditioning ducts are oversize and readily accessible. Fig. 9 shows a general view of the cooling plant, on the left being the compressors and condensers, in the center the cyclone air pumps, then the vacuum and air-compressor equipments, and to the right are the emergency power units, which are two Bardco plants consisting of a Ford *V-8* motor driving a 5-kw generator, controlled by relays which operate on failure of the city power supply. These generators will take over the load of the developing and printing equipment within 5 seconds of power failure. Less than two weeks after the laboratory was put into operation, a power failure of some hours' duration throughout Burbank caused the emergency equipment to assume the load until all negative

which was already in process could be run through the developing machines.

Film coming into the laboratory is routed through the shipping and receiving room, where it is separated and sent to the respective breakdown rooms. In the case of the sound-track negative, the "Hold and "NG" takes are broken out of the rolls and only the "Choice" takes processed. The "NG" takes are held for 72 hours, and if no call is made for them by the production office they are spliced into 1000-ft rolls and used for printing sound-track dailies. A Bell & Howell positive type splicer is installed in the breakdown room, and an early morning shift splices the "NG and "Hold" takes before the afternoon breakdown crew comes on duty. The "Hold" takes are retained in the outside vault until the picture is released, at which time they are also spliced and used for printing. Even though the latter group of rolls be held for a year, the stock is still suitable for printing purposes, as it is from 8 to 10 printer points faster than standard positive when new, and at the end of a year is still several points faster than the latter. No new print stock is used for dailies, there being a surplus of "Out" takes after all sound dailies are printed, this excess being used for printing a dupe negative off the cutting sound and picture prints, from which work prints are made for the music and re-recording departments in the studio, for use during scoring and dubbing operations.

Picture negative is delivered to the picture breakdown room, where all timing tests are broken out of the rolls before development. Although the "Test" system is employed for picture timing, the negative bath is set by a combination of sensitometric, photographic, and chemical tests to produce a gamma of 0.65 at $7^1/_2$ minutes development time. Each "Choice" take has a short section of test exposure which is developed at normal time and inspected in the negative timing room. Changes in time of development as indicated by the timing operator are made, and the work is processed accordingly. All takes whether "Choice," "NG," or "Hold" are developed.

Both types of negative are delivered from the drybox terminals to their respective negative assembly rooms. The "Choice" takes of pictures are broken out of the negative and assembled into 1000 ft rolls for printing. The sound-track negative, which is all of the ultraviolet push-pull type, is measured for density, and the scenes are then spliced into rolls for printing. This work is usually handled between 4 P. M. and midnight, by which time all production work

has usually ceased. The printing and positive developing machine crews report at 5 A. M. and all dailies are timed and printed by 9 A. M., at which time the synchronizing crews report. As soon as the reels are synchronized they are run in the projection rooms and delivered to the studio.

Optical printing, trick photography, and titles are made by the process department on the main studio lot and the negative is sent to the laboratory for processing. All separate sound-track prints for re-recording purposes are made on Eastman type *1361* fine-grain stock, printed by the day shift after the dailies are finished, as it is necessary to increase the time of development of the fine-grain stock by cutting in additional tanks in the developing section. The fine-grain composite master print used for printing the foreign duplicate negatives is exposed on Eastman type *1365* stock, and is developed in the picture negative developer to a gamma of 1.25. The duplicate negatives are developed in the special machine set aside for that purpose, and additional sets of air-squeegee jets are installed between the wash tanks and the dryboxes to remove all water spots, to which this film is especially sensitive.

From the above discussion it can be seen that the laboratory is able to turn out high-quality work with no part of the process impaired because of the requirements for speed.

DISCUSSION

MR. CRABTREE: We in the research field often hesitate to recommend new formulas, because we think that possibly the laboratories already have too many. Just what is the feeling of a laboratory superintendent toward new formulas? Does he have spare tanks, so that he can try them out, and how big a job is it to change over to something different from what he is using?

MR. SPRAY: It is not the formula as originally written on paper that counts, but the maintenance of that formula in a certain definite concentration at all times. In other words, it is a standardization problem, rather than so many grams of this and so many grams of that. It is a matter, in other words, of chemical control. Perhaps for negatives where we want a little more contrast, or for sound-track negatives, particularly in variable-area where we like to build up a good black, getting our density rather through development than through exposure, we use a developer which is a little more energetic and we go to a little higher gamma. But outside of that we are not particularly interested in the formulas, as such; we are rather interested in what they attempt to do.

MR. CRABTREE: Do you have any spare systems or spare tanks? How many different solutions with accompanying replenishing systems do you have in the laboratory?

MR. SPRAY: We have enough different solutions to satisfy the requirements of the different emulsions. Each is in a separate system. We do not try to put different emulsions through one bath.

MR. CRABTREE: I think that Mr. Gage said that he had eight at the time of the last convention in Hollywood. I wondered whether the number had increased.

MR. HYNDMAN: Each laboratory has the number of formulas and pieces of equipment for those formulas that are necessary within economic demand. In other words, some laboratories develop negative sound-track, negative pictures, and negative dupes, all in the same bath; whereas other laboratories develop each of these materials in a separate solution. To my knowledge there is no laboratory in Hollywood or in New York that has a developing machine in which experimental testing can be done. If any formula were to be tested experimentally to ascertain whether it were suitable, it would be necessary to cut production on at least one unit for that time. Unfortunately, for individualized testing it is quite common practice to have all the developing machine units tied into the same circulating system. Consequently, the cost of making an experimental test of a formula is often very high, because, depending upon the laboratory—1000 to 9000 gallons of the developer have to be mixed.

MR. CRABTREE: MGM, for instance, has a number of small units for negative development, each complete in itself. It would not seem to be a very difficult matter to try out an experimental developer under that system.

MR. HYNDMAN: I believe that MGM is the only laboratory in the United States that has that system; all other laboratories have the centralized circulation system.

I did not quite gather whether you meant that possibly the laboratories were against testing a new formula or were not willing to change from their present standard. I believe any laboratory is willing to try any formula that is recommended provided it can be adapted partially to their conditions before the formula is put into the machine. In other words, it may be necessary to cut down or raise the concentrations of certain chemical constituents to meet their processing conditions.

MR. BEST:* Answering Mr. Crabtree's question regarding spare tanks and facilities for trying out experimental developers, two of the developing machines are equipped with spare tanks in the developer section. We have frequently used these tanks for experimental developers as well as to speed up the change-over from one type of developer to another in the same machine.

Unlike a continuously operated release print laboratory, all developers are dumped into the sewer from time to time and entirely new solutions mixed. There are normally six solutions stored in the basement, these being the picture positive, process key positive, picture negative, process picture negative, dupe picture negative, and sound-track negative. Any of these developers can be pumped to any machine in the plant, but are normally pumped to the machine reserved for the work for which the developer is designed.

There is usually an empty storage tank available in the basement, and it is

* Communicated.

easy to mix up the minimum of 400 gallons of solution required to operate the tanks and circulating system and try out any new developer recommended by the film manufacturers. That was one of the reasons for installing the spare developing tanks, so that the regular work could go on undisturbed, and during a breathing spell the auxiliary tanks with the special developer could be threaded to the input rack and hypo tanks, bridging out the regular developer, all at 5 minutes' notice. During recent months, new sound-track negative formulas have been tried out under these conditions, and where these experiments have proved the new formula had advantages over the one in use, changes were gradually made in the regular formula to incorporate these improvements.

No new formula recommended by the makers of the film we are using is ever passed by without adequate experimental tests and we feel that the studio laboratories in particular are very open-minded on the subject of advancements in this phase of the art.

DR. H. P. GAGE: How were the n. g. takes later used for printing?

MR. SPRAY: The sound-track prints having just a small portion of their film used for that purpose, can be used again to print a picture or a track on the opposite side.

MR. KELLOGG: Mr. Hyndman spoke of the adaptation of a developer to particular laboratory conditions. It is difficult for me to see that developer formulas need to be materially changed for different laboratories, unless for the purpose of conforming to what the operators are accustomed to. As far as sound-tracks go, all who are making variable-area tracks are shooting for about the same final result and the same is true of those who are working with variable-density recordings. Practically the same thing could be said about picture quality. There may be a difference in the speeds of operation of the developing machines, or in their agitation or filtering systems. Apart from these factors, why should there be differences?

MR. SPRAY: There should not necessarily be any differences; but the end is what we are trying to arrive at. RCA wants a definite density at a definite gamma, and we give it to them. You must remember that when sound came out first, there were not any published formulas for that purpose.

The making up of a formula in a small amount is one thing, but the maintaining of it continuously is an entirely different problem. We at the Ace Laboratory have had a bath running over a couple of years that has not been remade at all, but has been kept continuously operating. That is an entirely different problem from the publishing of a formula made up for the moment. Such a lot of things take place over a long period of time under operating conditions.

MR. KELLOGG: I suppose it is a difficult thing to get a complete answer to my question. I wondered how much of it was purely psychological, or a matter of what people are familiar with, and how much of the difference is really necessitated by inherent differences in the developing machines and their set-up.

MR. SPRAY: One important factor that does not come out in formulas is the speed of the film through the bath.

MR. IVES: The formula as you write it on paper is that of absolutely fresh and unused developer. In the machine system, its state is quite different. It is at all times in a partially exhausted condition, because it does not just hit the film and run off into the sewer. Consequently, the formula as used in the product of the

original formula, plus the treatment which has occurred is the course of running a certain amount of film through it in a certain machine, with exposure to various local conditions. Since the machine designs vary widely, the results obtained with a given starting formula vary rather widely from one laboratory to another.

In order to have the activity of the bath consistent with the running speed of the machine, some adjustment of the activity is frequently necessary. Of course, economics also enter into these things.

MR. KELLOGG: Would it be right to say that the principal differences in requirements of different laboratories to achieve essentially the same result (for example, to process a variable-area sound recording—up to a certain desirable density) would be the feet per minute that the film travels, and the equipment for producing agitation or circulation? Those are the only things that seem to me necessarly different in different laboratories. If it were not for such things as I have just mentioned, which are due to differences in equipment, you might well standardize on a formula and method of replenishment. Is that right?

MR. EVANS: When four laboratories say they are using the same formula, they are not, in the ordinary case. They start out with the same formula, but the technic of replenishment leads to a different formula in all four laboratories. Agitation and temperature and speed of the machine all enter into the picture, very decidedly; but in addition, there is the difference that four persons, each using his own technic of replenishment, will arrive at four different stable conditions.

I would like to enter a plea, now that we have analytical methods for developers, that we start writing the formula for the used developer, and not the one that we start with.

MR. SPRAY: One more factor enters: Emulsions are kept remarkably uniform. The variations in them are very small, especially considering the fact that a photographic emulsion is one of the most complicated chemical products made on a large scale. They do vary somewhat, however, enough to cause us to change our speed of development and time of exposure.

DR. NICHOLSON: At the Signal Corps Photo Laboratory we are constantly supplying prints of negatives that may have been exposed and developed any time during the last twenty-five years. These negatives include the World War negatives, which were developed somewhere near the front lines without any sensitometric control. The development gamma of these negatives probably varies from 0.50 to 0.90.

The superintendent of the laboratory inspects the negative and chooses a positive gamma that will produce an approximate overall gamma of 1.30. His choice may be any positive gamma from 1.50 to 2.50.

Regardless of the development gamma our positive developing machine must be operated at top speed in order to meet our release schedule. The maximum developing time with the elevators all the way down is $4^1/_3$ minutes. The minimum development time with the elevators all the way up is $2^3/_4$ minutes. The first requirement of our positive developer, therefore, is that a gamma of at least 2.50 is obtained in $4^1/_3$ minutes and a gamma of not more than 1.50 is obtained in $2^3/_4$ minutes.

All prints are exposed at the same speed with the same printing lamp. The

voltage on the printing lamp can be varied from 90 to 125 volts. Below 90 volts the lamp becomes unstable and above 125 volts the life of the lamp is decreased.

The second requirement of our positive developer, therefore, is that at a development gamma of 2.50 the developer should not give too much density to permit printing light negatives with 90 volts on the printing lamp, and that at a development gamma of 1.50 the developer should give sufficient density to permit printing heavy negatives with 125 volts on the printing lamp.

Experience has taught us that these two requirements of gamma and density are approximately fulfilled if a development of $3^3/_4$ minutes gives a gamma of 2.20 and the density of step *6* on an Eastman II*B* sensitometric strip is 0.60. No standard developer will give these results. In order to get these results a developer that gave a gamma less than 2.20 and a density less than 0.60 in $3^3/_4$ minutes had to be mixed and put into the developing machine. By slight increases in the developer constituents and many tests, the desired results were finally obtained.

This process is called adapting a positive developer to suit the requirements of a particular laboratory. Developers will always have to be adapted to meet particular requirements unless developing machines and laboratory methods become standardized.

Mr. Crabtree: What method of lubrication of the film is employed?

Mr. Spray: At Hollywood they use the edge-waxing system, which has been found satisfactory.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Acoustical Society of America, Journal

12 (July 1940), No. 1

Acoustic Impedance of Commercial Materials and the Performance of Rectangular Rooms with One Treated Surface (pp. 14–23) — L. L. Beranek

Sound Control Apparatus for the Theater (pp. 122–126) — H. Burris-Meyer

Sound Measurement Objectives and Sound Level Meter Performance (pp. 150–156) — J. M. Barsto

American Cinematographer

21 (August 1940), No. 8

The Light-Meter and Its Relatives (pp. 342–344) — D. B. Clark

Cinematographers Show How to Achieve Production Economies (pp. 360–362)

British Journal of Photography

87 (June 28, 1940), No. 4182

Progress in Colour (pp. 313–314)

87 (July 5, 1940), No. 4183

Progress in Colour (pp. 323–324)

87 (July 19, 1940), No. 4185

Progress in Colour (pp. 351–352)

Communications

20 (July 1940), No. 7

Fundamentals of Television Engineering, Pt. 10 (pp. 7–8, 18–19) — F. Everest

Electronics

13 (July 1940), No. 7

Embossing at Constant Groove Speed—a New Recording Technique (pp. 26–27, 62–64) — E. E. Griffin

A Picture Signal Generator, IV (pp. 28–31) — J. A. Brustman and M. P. Wilder

International Projectionist
15 (June 1940), No. 6

Sound Reinforcing System Data (pp. 7–8, 11–12, 29–30)	P. P. MELROY
Efficient Projection Supervision (pp. 22–22)	H. RUBIN

Motion Picture Herald (Better Theatres Section)
140 (July 29, 1940), No. 4

The Search for Better Projection Light (p. 10)	F. H. RICHARDSON
Reviewing the New D-C Arc Lamps (pp. 35–36, 38–40)	

Optical Society of America, Journal
30 (July 1940), No. 7

Production Color Analysis of Kinescope Screens (pp. 295–296)	T. B. PERKINS
Optimum Efficiency Conditions for White Luminescent Screen in Kinescopes (pp. 309–315)	H. W. LEVERENZ

1940 FALL CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

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HOLLYWOOD, CALIFORNIA
OCTOBER 21st–25th, INCLUSIVE

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Headquarters

Headquarters of the Convention will be the Hollywood Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Daily hotel rates to SMPE delegates will be as follows (European Plan):

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00–14.00
Parlor suite and bath, 2 persons	12.00–16.00

Room reservation cards will be mailed to the membership early in September, and should be returned to the Hotel immediately to be assured of satisfactory accommodations.

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	*Railroad Fare (round trip)*	*Pullman (one way)*
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	135.00	23.65
Detroit	106.75	19.20
New York	135.00	22.85
Rochester	124.05	20.50
Cleveland	111.00	19.20
Philadelphia	135.00	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips. Arrangements may be made with the railroads to take different routes going and coming, if so desired,

but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems. Technical sessions will be held in the *Blossom Room* of the Hotel. Several evening meetings will be arranged to permit attendance and participation by those whose work will not permit them to be free at other times. The Local Papers Committee is collaborating closely with the General Papers Committee in arranging the details of the program.

Studio Visits

The Local Arrangements Committee is planning visits to several studios during the Convention week. Details will be announced in the next issue of the JOURNAL. Admittance to the studios will be by registration card or Convention badge only.

New Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore Rooms* of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the General Office of the Society at the Hotel Pennsylvania, New York, N. Y

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, October 23rd, in the *Blossom Room.* A feature of the evening will be the annual presentations of the SMPE Progress Medal and the SMPE Journal Award. Officers-elect for 1941 will be announced and introduced, and brief addresses will be delivered by prominent members of the motion picture industry. The evening will conclude with entertainment and dancing.

The Informal Get-Together Luncheon will be held in the *Florentine Room* of the Hotel on Monday, October 21st, at 12:30 P. M.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. L. L. Ryder, *hostess*, and the Ladies' Committee. A suite

will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; Beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the West, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

Those who wish to visit San Francisco may arrange for stop-over privileges when purchasing their railroad tickets. Arrangements have been made with the Hotel Mark Hopkins for single accommodations for $5 daily and double with twin beds for $7, both with baths. The Fairmont Hotel also extends a rate of $4 single and $6 double, with bath. Reservations may be made by writing directly to the Hotel.

W. C. KUNZMANN,
Convention Vice-President

SOCIETY ANNOUNCEMENTS

NOMINATIONS OF SOCIETY OFFICERS FOR 1941

At a meeting of the Board of Governors held at New York on July 19th, the following nominations of officers for 1941 made by the nominating committee were confirmed:

President	**E. A. Huse
Executive Vice-President	*H. Griffin
Editorial Vice-President	*A. C. Downes
Convention Vice-President	*W. C. Kunzmann
Secretary	*P. J. Larsen
Treasurer	*G. Friedl, Jr.
Governors (Two to be elected)	*M. C. Batsel
	*F. E. Carlson
	*E. K. Carver
	**L. L. Ryder

* Resides in East ** Resides in West

All the officers and governors are elected for two years with the exception of the Secretary and Treasurer, whose terms are one year each. Two of the above-mentioned nominees for Governor are to be elected.

Officers whose terms expire December 31, 1940, are as follows:

E. A. Williford, *President*
S. K. Wolf, *Past-President*
N. Levinson, *Executive Vice-President*
J. I. Crabtree, *Editorial Vice-President*
W. C. Kunzmann, *Convention Vice-President*
J. Frank, Jr., *Secretary*
R. O. Strock, *Treasurer*
M. C. Batsel, *Governor*
H. G. Tasker, *Governor*

Ballots for voting on these nominees are being mailed to the voting membership of the Society, and announcement of the results will be made at the 47th Semi-Annual Banquet on October 23rd, during the approaching Fall Convention at Hollywood.

ATLANTIC COAST SECTION

At a recent meeting of the Board of Managers of the Atlantic Coast Section, the following nominations of officers for 1941 were made:

Chairman	R. O. Strock
Secretary-Treasurer	J. A. Maurer

Managers (Three to be elected for two-year terms)	P. C. GOLDMARK H. E. WHITE W. H. OFFENHAUSER, JR. R. B. AUSTRIAN
Managers (Three to be elected for one-year terms)	H. B. CUTHBERTSON F. C. CAHILL, JR. J. A. NORLING M. E. GILLETTE

Officers and managers of the Section whose terms expire December 31, 1940, are as follows:

P. J. LARSEN, *Chairman*
D. E. HYNDMAN, *Past-Chairman*
J. A. MAURER, *Secretary-Treasurer*
H. GRIFFIN, *Manager*

In a proposed amendment of the By-Laws, described in following paragraphs, the Boards of Managers the Sections of the Society have been increased in size. Up to the present, a Board of Managers has consisted of Section Chairman, Section Past-Chairman, Section Secretary-Treasurer, and two Managers. In view of requests from the Sections, the number of Managers has been increased to six, making a total of nine members of the Board.

PROPOSED AMENDMENTS TO THE BY-LAWS

At the meeting of the Board of Governors at New York on July 19th, the following amendments to the By-Laws were proposed and approved for publication in the JOURNAL and subsequent action by the members of the Society in meeting at the forthcoming Convention at Hollywood, October 21–25th. Both the present wording and the proposed wording are here given:

BY-LAW XI, SEC. 4, OFFICERS

Present Wording.—Each Section shall nominate and elect a chairman, two managers, and a secretary-treasurer. The Section chairman shall....

Proposed Wording.—The officers of each Section shall be a chairman, six managers, and a secretary-treasurer. The Section chairmen shall automatically become members of the Board of Governors of the General Society, and continue in that position for the duration of their terms as chairmen of the local sections. All Section officers shall hold office for one year, or until their successors are chosen.

BY-LAW XI, SEC. 5, BOARD OF MANAGERS

Present Wording.—The Board of Managers shall consist of the Section chairman, the Section past-chairman, the Section secretary-treasurer, and two Active, Fellow, or Honorary members, one of which last named shall be elected for a two-year term, and one for one year, and then one for two years each year thereafter. At the discretion of the Board of Governors, and with their written approval, this list of officers may be extended.

Proposed Wording.—The Board of Managers shall consist of the Section chairman, the Section past-chairman, the Section secretary-treasurer, and six Active, Fellow, or Honorary members. The managers of a Section shall hold office for two years, or until their successors are chosen.

BY-LAW XI, SEC. 6, ELECTIONS

Present Wording.—The officers of a Section shall be Active, Fellow, or Honorary members of the General Society. They shall be nominated and elected to sectional office under the method prescribed under By-Law VII, Sec. 1, for the nomination and election of officers of the General Society. The word *manager* shall be substituted for the word *governor*. All Section officers shall hold office for one year, or until their successors are chosen, except the Board of Managers, as hereinafter provided.

Proposed Wording.—The officers and managers of a Section shall be Active, Fellow, or Honorary members of the General Society.

Not less than three months prior to the annual Fall Convention of the Society, nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the chairman of the Section, consisting of seven members, including a chairman. The committee shall be composed of the present chairman, the past-chairman, two other members of the Board of Managers not up for election, and three other Active, Fellow, or Honorary members of the Section not currently officers or governors of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The remainder of the procedure shall be in accordance with procedures specified for the election of officers of the General Society as described in By-Law VII, Sec. 1A, the word *manager* being substituted for the word *governor*.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXXV **October, 1940**

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JOURNAL
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PORTABLE TELEVISION PICK-UP EQUIPMENT *

G. L. BEERS,** O. H. SCHADE,† AND R. E. SHELBY††

Summary.—*Spot news, athletic events, parades, etc., form an important source of television program material. In the spring of 1938 field experiments were started in New York City with mobile television pick-up equipment. Two telemobile units were used each of which was about the size and shape of a twenty-five passenger bus and weighed ten tons. The limitations of these telemobile units are discussed. Light-weight television pick-up equipment has recently been developed. The new equipment includes a small Iconoscope camera, camera auxiliary, camera control and synchronizing generator units, and an ultra-high-frequency relay transmitter and receiver. Most of the units are about the size of a large suitcase and weigh between 40 and 70 pounds. Each of the units is described and some of the practical applications of the equipment are indicated.*

In the spring of 1938 field experiments were started in New York City with mobile television pick-up equipment. Two telemobile units were used, one of which contained standard rack-mounted equipment for two cameras and the other housed a 159-megacycle, 300-watt transmitter. Each unit was about the size and shape of a twenty-five passenger bus and weighed ten tons. The total power required to operate both units was approximately twenty kilowatts. Field tests with the mobile units have definitely proved their usefulness in providing entertaining television programs. The size, weight, and power requirements of these units, however, have imposed definite restrictions on their use. In order to minimize these restrictions light-weight portable television pick-up equipment has recently been developed. It is the purpose of this paper to describe the several units of this equipment and indicate some of its possible applications.

GENERAL CHARACTERISTICS OF THE EQUIPMENT

Past experience with all types of television pick-up equipment has shown that it is desirable to locate all the control equipment at

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some central point if effective program supervision with a minimum of personnel is to be obtained. It is therefore essential that provision be made in portable television pick-up equipment so that long lengths of camera cable can be used between the control equipment and the cameras. This requirement was responsible, to a considerable extent, for the division of the equipment into the several units shown in the diagram of Fig. 1. In this diagram the units for a complete system with a single camera are outlined by the solid lines. The additional units required for a second camera are shown by the dotted

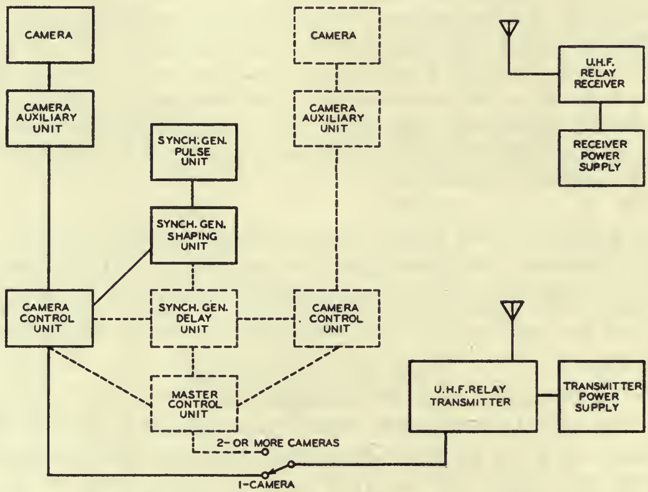

FIG. 1. Block diagram of complete portable television pick-up system.

lines. The only units that must be duplicated to add a third camera are the camera auxiliary and camera control units. The receiver shown in the diagram is normally located at or near the main television transmitter and is therefore not a part of the equipment that must be transported to the remote pick-up point.

The equipment is designed to produce synchronizing signals in accordance with the RMA standards. All the video-frequency amplifiers are adjusted to pass a frequency band from 30 cycles to 5 megacycles. Lengths of camera cable up to 500 feet can be used between the camera and camera control equipment so that any two cameras can be separated by distances up to 1000 feet.

The equipment operates from any suitable 110-volt, 60-cycle, single-phase power supply system. The power consumption for the portable equipment with one camera, two cameras, and three cameras is 1400, 2000, and 2500 watts, respectively.

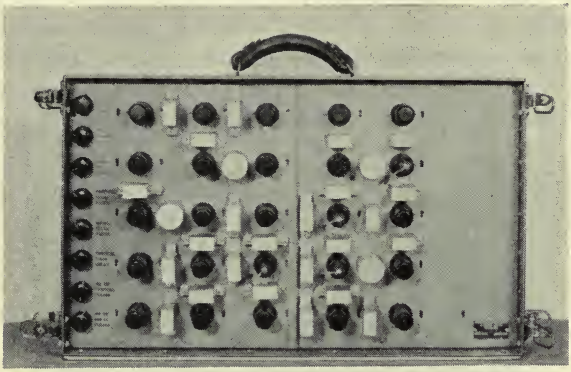

FIG. 2. Synchronizing generator shaping unit—tube side, cover removed.

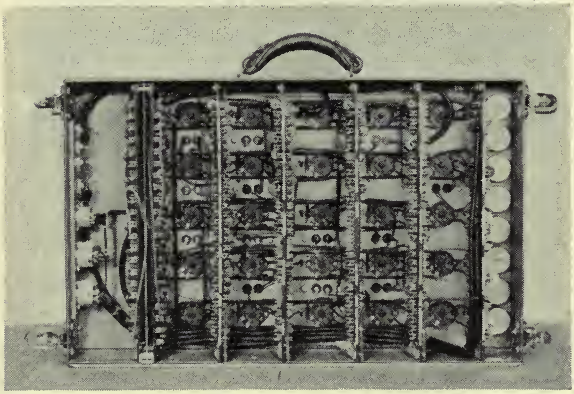

FIG. 3. Synchronizing generator shaping unit—circuit component side, cover removed.

All the units are designed to make the tubes and circuit components as accessible as possible. The suitcase type of construction used for the camera auxiliary, camera control, master control, and three synchronizing generator units is illustrated by Figs. 2 and 3. These photographs show both sides of the synchronizing generator shaping

unit. The accessibility of the tubes on one side of the unit and the circuit components on the other is clearly illustrated. The central chassis portion of the unit is welded to the outside case to form a rigid unit. A view of the complete unit with the side covers in place is shown in Fig. 4. The overall dimensions of the suitcase type units are 8 × 15 × 25 inches, and their weights vary between 45 and 72 pounds. The camera weighs 28 pounds and its tripod 30. The weights of the transmitter and its power supply unit are 60 and 190 pounds. The total weights of the portable pick-up equipment, less

FIG. 4. Synchronizing generator shaping unit with covers in place.

interconnecting cables for one, two, and three cameras, are 550, 850, and 1050 pounds, respectively. These weights can each be reduced by 250 pounds when the equipment is used at locations from which the television signals can be sent by coaxial cable to the main transmitter. The camera cable used with the equipment weighs approximately 0.6 pound per foot. If 500-foot cables are used with each of three cameras, the total weight of these cables is approximately the same as the total weight of the equipment units. The functions of the individual units are discussed in the following sections.

Camera.—In order to keep the camera dimensions as small as possible the camera was designed to use the new $4^1/_2$-inch Iconoscope

Development work on small Iconoscopes has been in progress for several years. As the dimensions of an Iconoscope are made smaller, with a corresponding reduction in the mosaic area, a loss in resolution and sensitivity is normally expected. A new gun structure that has recently been developed has made it possible to obtain adequate resolution from the $4^1/_2$-inch Iconoscope. Tests on this tube have

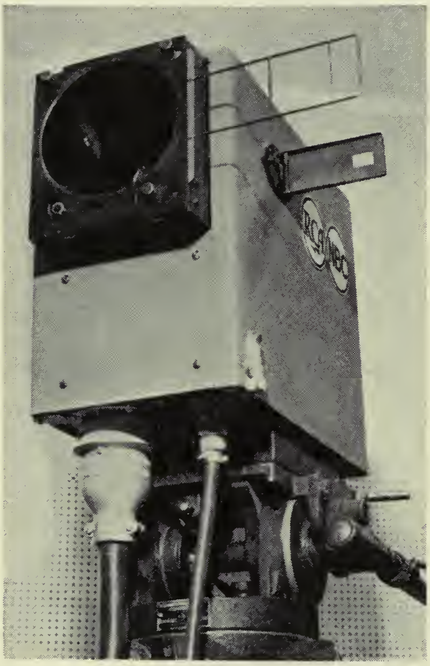

FIG. 5. Portable television camera on tripod.

shown also that its operating sensitivity when using a lens of a given aperture is substantially the same as that of the standard Iconoscope. This unexpected sensitivity is attributed to the smaller spacing between the several tube elements, resulting in a more efficient collection of the secondary electrons. This increase in the electron-collecting efficiency enables the tube to be operated at a higher average beam current for a given ratio of signal to dark spot voltage.

Fig. 5 is a photograph of the camera mounted on a standard motion picture tripod, and shows the wire frame view-finder used by the

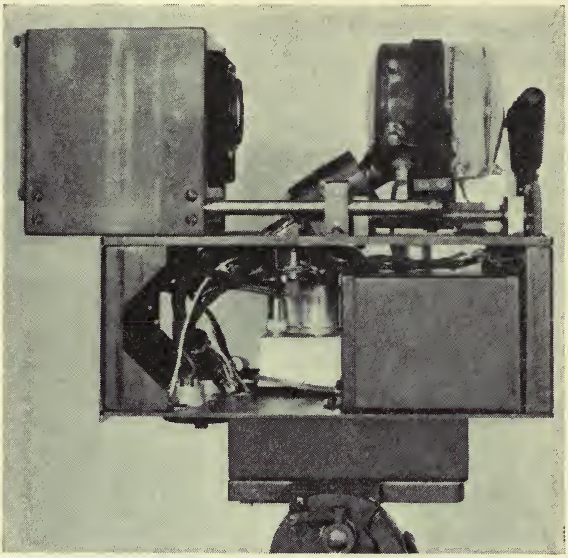

FIG. 6. Right side of portable television camera, cover removed.

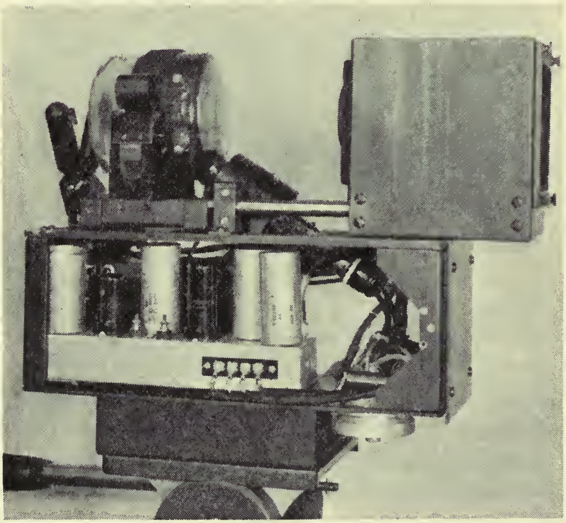

FIG. 7. Left side of portable television camera, cover removed.

cameraman to keep the scene to be televised within the field of the camera. Focusing is done remotely by observing the picture on the Kinescope in the camera control unit. A selsyn motor at the camera-control unit is used to operate a similar motor in the camera which in turn drives the lens carriage.

The internal construction of the camera is shown by the photographs in Figs. 6 and 7. The focusing motor is housed within the rectangular shield which is visible in the lower right-hand corner

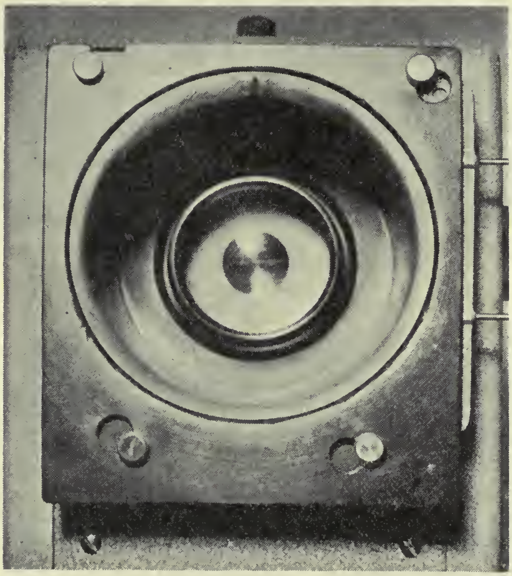

FIG. 8. Portable television camera—lens mounting.

of Fig. 6. The two-stage preamplifier, which can be seen in Fig. 7, is used to raise the picture signals derived from the Iconoscope to a satisfactory level for transmission over a short length of coaxial cable to the camera auxiliary unit. The Iconoscope with its deflection yoke, the lens carriage, and the two shielded bias lights, which are mounted in back of the Iconoscope, are all clearly shown in this photograph.

Fig. 8 shows the lens mounting arrangement. Lenses are interchanged by loosening the four thumbscrews shown in the photograph and then rotating the lens mounting slightly in a counter-clockwise

direction. The complete lens mounting assembly can then be removed by pulling it forward. Another lens is attached to the camera by reversing the procedure.

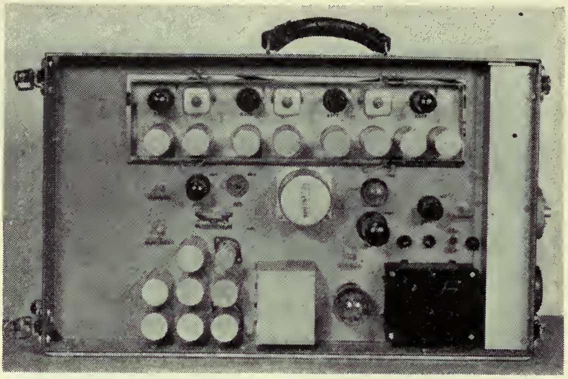

FIG. 9. Camera auxiliary unit—tube side, cover removed.

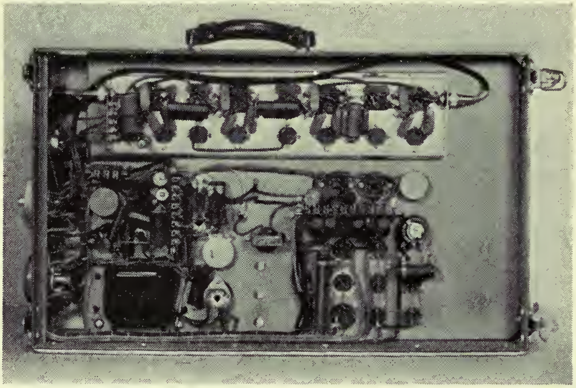

FIG. 10. Camera auxiliary unit—circuit component side, cover removed.

Camera Auxiliary Unit.—The problem of obtaining satisfactory deflection of the Iconoscope beam when a long length of camera cable is used is greatly simplified when the horizontal deflection power is developed in or near the camera. The use of a camera auxiliary unit makes it possible to meet this requirement and at the same time keep the dimensions and weight of the camera as small as possible.

In addition to the horizontal deflection circuits the camera auxiliary unit contains a 4-stage video-frequency amplifier, Iconoscope blanking and protection circuits, and a power-supply rectifier. This unit is connected to the camera through an 8-foot length of camera cable and is usually located between the legs of the camera tripod.

The video-frequency amplifier, which contains both a high-frequency peaking and low-frequency losing circuit, is used to raise the video-frequency signal from the preamplifier in the camera to a sufficient level so that a satisfactory signal-to-noise ratio is obtained at the receiving end of a 500-foot length of camera cable. This ampli-

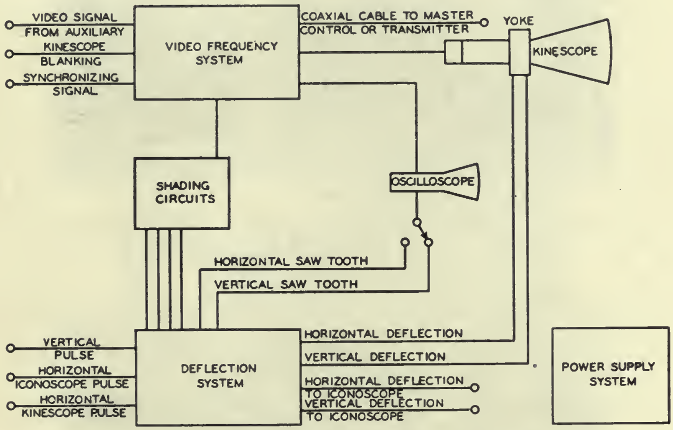

FIG. 11. Block diagram of camera control unit.

fier is assembled as a complete unit on a small chassis which is flexibly mounted in an opening in the main chassis of the camera auxiliary unit. The construction of the amplifier and the method of mounting are illustrated in Figs. 9 and 10. It will be noted that this construction maintains the general arrangement of having all the tubes accessible from one side of the unit and the circuit components and wiring accessible from the other.

The voltage wave developed across the Iconoscope deflection yoke is used to produce a vertical Iconoscope blanking pulse. A protective circuit is provided by which the grid of the Iconoscope receives a high negative bias if for any reason the deflection of the Iconoscope beam is interrupted, thereby preventing damage to the Iconoscope mosaic. Horizontal sawtooth waves produced in the camera-

control unit are transmitted to the camera auxiliary unit over a flexible coaxial line included in the main camera cable. These waves are amplified by a two-stage amplifier in this unit and fed to the

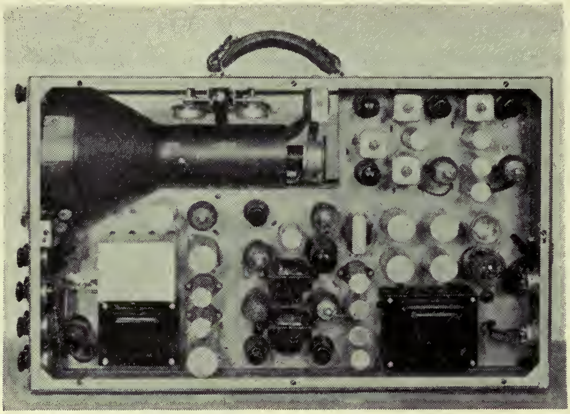

FIG. 12. Camera control unit—tube side, cover removed.

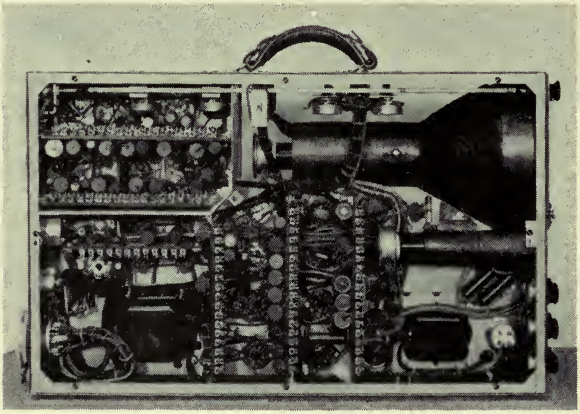

FIG. 13. Camera control unit—circuit component side, cover removed.

Iconoscope deflecting yoke through a step-down transformer. The power-supply rectifier in the camera auxiliary unit supplies anode potentials to all the tubes in both this unit and the camera. A 15-

conductor rubber-covered camera cable is used to provide the electrical connections between the camera auxiliary and camera control units. The outside diameter of this cable is slightly under one inch. As previously stated, lengths of camera cable up to 500 feet can be used between the camera auxiliary and camera control units.

Camera Control Unit.—The camera control unit is normally the central control point at which all the operating adjustments are made while the equipment is in use. The several functions of this unit are

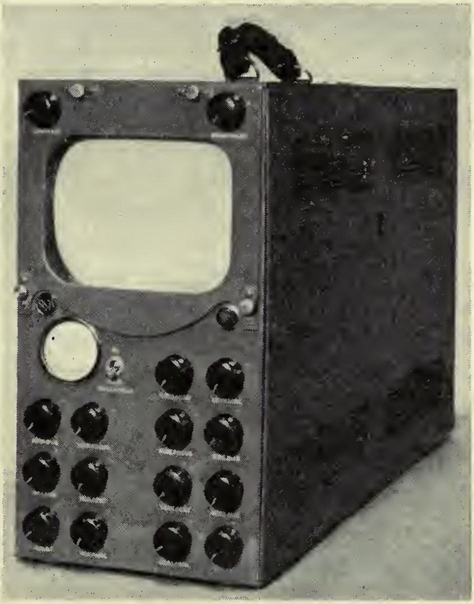

FIG. 14. Camera control unit—front view.

indicated by Fig. 11. The video-frequency system shown in this diagram amplifies the video-frequency signals received over the camera cable from the camera auxiliary unit. Blanking and shading signals are inserted in this portion of the system. The shading signals used are sawtooth and parabolic waves at both line and field frequencies. Controls are provided for varying both the amplitude and phase of these signals. In case only a single camera is used synchronizing signals can be inserted in the video-frequency system of the camera control unit. Suitable signal potentials are supplied to the 7-inch Kinescope which is used to monitor the picture and the 2-inch

oscilloscope which is used to observe the wave-shapes of the picture signals. The video-frequency system is also designed to feed a 2-volt peak-to-peak signal to a 75-ohm coaxial cable. Controls are provided for varying the video-frequency gain and the amplitude of the Kinescope blanking signals.

In the deflection system line and field frequency impulses received from the synchronizing generator are used to produce sawtooth waves which are supplied to the Iconoscope, Kinescope, and oscilloscope. Provision is made in the synchronizing generator delay unit for delaying the Kinescope horizontal deflection impulses with respect to the Iconoscope impulses. Facilities are included in the camera-control unit for keystoning the horizontal deflection of the Iconoscope. A switch is provided so that horizontal deflection of the oscilloscope at either line or field frequency can be obtained. Kinescope and Iconoscope width, height, and centering controls are included. The line and field frequency sawtooth waves produced in the deflection system are also used as shading signals in the video-frequency system. The power-supply system includes a high-voltage rectifier for supplying anode potentials to the Iconoscope and Kinescope. A low-voltage rectifier is used to supply anode potentials to all the other tubes in the camera control unit. Focus and bias controls for the Kinescope and Iconoscope are included in this portion of the system.

Figs. 12 and 13 show both sides of the camera control unit with the side covers removed. The front of this unit showing the Kinescope, oscilloscope, and the several control knobs is illustrated by the photograph in Fig. 14. A metal cover is supplied which protects these tubes and knobs when the equipment is not in use.

Master Control Unit.—When more than one camera is used to televise a desired scene some means must be provided for switching from one camera to another and for monitoring the "on the air" picture. In the portable pick-up equipment these requirements are filled by the master control unit. Fig. 15 shows the several functions of this unit. The video-frequency system amplifies the signals received from the camera control unit and supplies them to the Kinescope and oscilloscope. Synchronizing signals are normally inserted in the video-frequency system of the master control unit. The line amplifier in this unit is designed to provide a 4-volt peak-to-peak signal across a 75-ohm line. A separate 75-ohm output circuit is included which can be used to feed an additional monitor unit. The video-

frequency system is provided with an interlocked switching arrangement by which any one of four input signals can be selected, amplified, monitored, and fed to the outgoing line. Indicator lights on both the master control unit, each camera control unit, and camera show which camera is "on the air."

The deflection system for the master control unit employs synchronizing and deflection circuits essentially the same as those used in television receivers. The picture observed on the Kinescope in the master control unit is therefore an indication of the performance to be expected at the receiving locations.

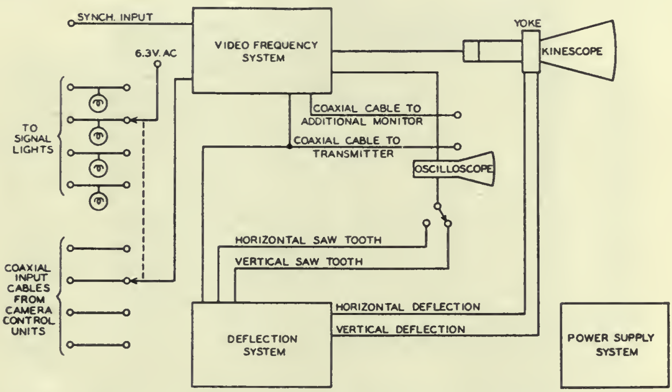

FIG. 15. Block diagram of master control unit.

The low-voltage and high-voltage rectifiers used in the master control unit are similar to those included in the camera control unit. Fig. 16 is a front view of the master control unit and shows the switching and indicator light arrangement.

Synchronizing Generator.—The portable synchronizing generator is designed to produce pulses in accordance with the standards of the Radio Manufacturers Association. The synchronizing generator is divided into three units: the pulse unit, the shaping unit, and the delay unit.

Pulse Unit.—The pulse unit contains an electromechanical pulse generator for producing 26,460- and 60-cycle pulses. This type of pulse generator was used because it gave the desired electrical characteristics with a minimum of equipment. This generator consists of a brass disk having 441 peripheral teeth and rotated by a 3600-rpm synchronous motor. This disk revolves inside a stationary

brass ring having 441 teeth on its inner circumference. The clearance between the teeth on the rotor and stator is approximately 0.012 inch. A single radial fin is used on the rotating disk in conjunction with a similar stationary fin to produce the 60-cycle pulses. D-c polarizing voltage is applied between the stators and the rotating disk through resistors. The current variations through the resistors in accordance with the changes in capacity produce the desired volt-

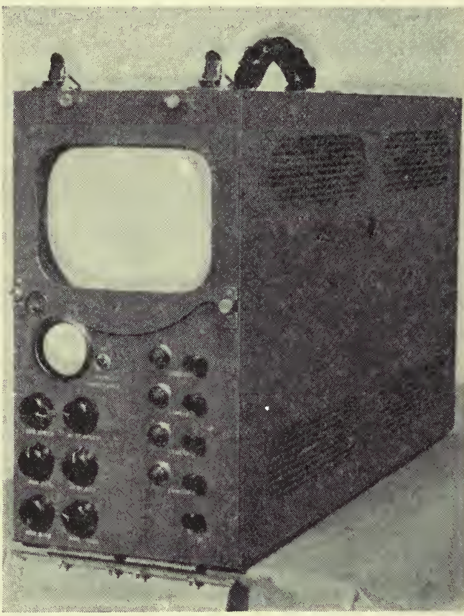

FIG. 16. Master control unit—front view.

age pulses. The use of a large number of teeth on both rotor and stator minimizes the effect of inaccuracies in the width of the teeth and the spacing between them, since each pulse is produced by the average change in capacity caused by each of the 441 teeth on the rotor and stator. In addition to the pulse generator the pulse unit contains tubes and associated circuits for shaping the pulses and for obtaining pulses at line frequency by selecting every other one of the 26,460 pulses. A power-supply rectifier to provide anode potentials for the complete synchronizing generator is also included in the pulse unit. Fig. 17 shows the tube side of the pulse unit. The

pulse generator is shown in the lower left-hand corner of the figure. The rotor and stator are completely surrounded by a bakelite housing.

Shaping Unit.—The shaping unit receives 60, 13,230, and 26,460-cycle pulses from the pulse unit. Four sets of pulses are provided by the shaping unit as follows:

(*1*) Iconoscope horizontal driving pulses
(*2*) Iconoscope vertical driving pulses
(*3*) Blanking pulses
(*4*) Synchronizing pulses

Although the synchronizing pulses are formed by combinations of several pulses the leading edge of each pulse is the leading edge of a

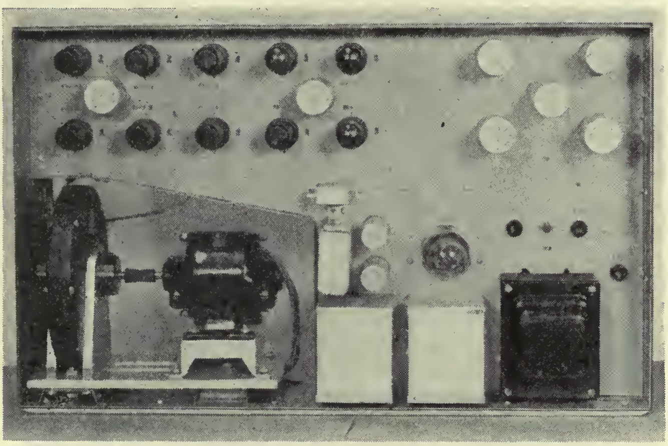

FIG. 17. Synchronizing generator pulse unit—tube side, cover removed.

26,460-cycle pulse. Controls are provided for varying the width of the several pulses. Photographs of the shaping unit with the side covers removed have been previously shown in Figs. 2 and 3.

Delay Unit.—When two or more cameras are connected to the control equipment through cables differing greatly in length, it is necessary to delay the driving pulses to the camera connected to the shortest cable so that the pulses returning to the control equipment from this camera correspond in time with those returning from the camera connected to the longest cable. The synchronizing generator delay unit contains an artificial line which is used to delay the driving pulses to any one of three cameras by an amount corre-

sponding to any normal length of camera cable up to 500 feet. Buffer tubes are used between the switches and the artificial line so that the characteristics of the line are not affected by the various lengths

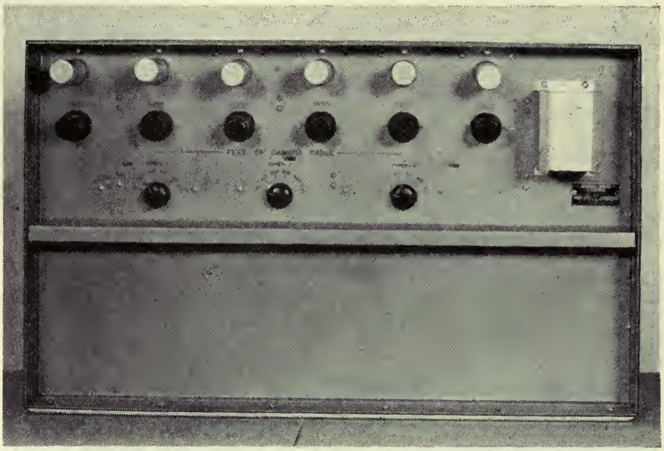

FIG. 18. Synchronizing generator delay unit—tube side, cover removed.

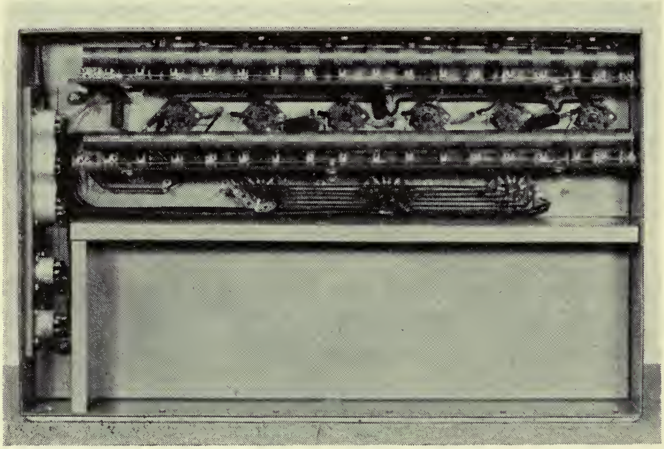

FIG. 19. Synchronizing generator delay unit—circuit component side, cover removed.

of camera cable. Switch positions are provided for 50, 100, 200, 300, 400, and 500-foot lengths of cable. Fig. 18 is a photograph of the tube side of the delay unit, and shows the switch knobs for varying

the delay for each camera. The photograph shown in Fig. 19 illustrates the construction of the artificial line and the circuit components used with the buffer tubes. The space in the bottom of both sides of this unit is used to carry spare tubes.

Relay Transmitter.—One of the requirements of any portable pick-up system is that some provision must be made for conveying

FIG. 20. Ultra-high-frequency relay transmitter—front view.

the signal from the remote point to the location where it can be utilized. The wide frequency band used in television makes this problem especially difficult. One obvious solution is of course a portable transmitter for relaying the signal from the remote pick-up point to a suitable receiving location near the main transmitter. An ideal transmitter for this type of work must be reasonably rugged, light in weight, and deliver sufficient power to provide a satisfactory service range. The ultra-high-frequency television relay transmitter was designed to meet these requirements. This transmitter is crystal-

controlled and will deliver a peak power of 25 watts at any specified frequency between 280 and 340 megacycles. The radio-frequency portion of the transmitter consists of four stages: crystal oscillator, two multiplier stages, and the power-amplifier stage. Two neutralized *1628* triodes are used in the power amplifier. All the circuits which are resonant at carrier frequency are "transmission line circuits." All the other r-f circuits are conventional *L-C* circuits.

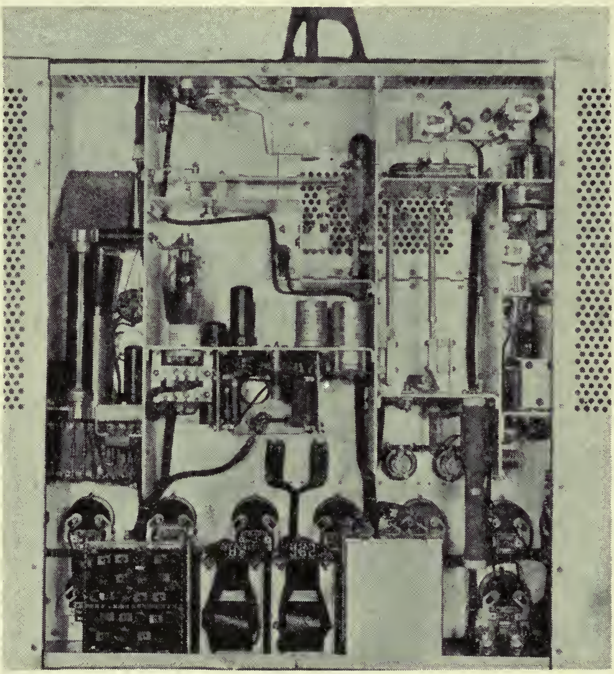

FIG. 21. Ultra-high-frequency relay transmitter—rear view, doors open.

The video-frequency portion of the transmitter consists of three stages adjusted to pass the frequency band between 30 cycles and 5 megacycles. An input of 2 volts peak-to-peak is sufficient for complete grid modulation of the power amplifier stage. The d-c component of the video signal is restored in the grid circuit of the modulator stage, and d-c coupling is employed between the modulator plate and the power-amplifier grids.

The monitoring system in the transmitter consists of a diode rectifier, a video-frequency amplifier, and a 2-inch oscilloscope. Provision is made so that the output of the video-frequency amplifier can be fed to a master control unit so that the complete picture can be monitored.

The transmitter output system is so arranged that either a coaxial line or balanced feeder system may be used. Small antennas having high directivity are readily obtainable at the transmitter frequency. A unidirectional array using eight half-wave elements has given a measured power gain of 12 in field tests.

Fig. 20 is a front view of the transmitter. The overall dimensions of this unit are $6 \times 24 \times 26$ inches. The antenna transmission line

FIG. 22. Ultra-high-frequency relay transmitter power-supply unit.

clamping unit is shown extending from the top of the transmitter unit. The monitoring oscilloscope is viewed through the circular opening in the upper right-hand corner of the picture. The meters at the bottom of the unit indicate the currents in the various tubes.

The rear view of the transmitter with the doors open is shown in Fig. 21. The location of the various circuit components, tubes, and transmission lines can be seen in this photograph.

Transmitter Power-Supply Unit.—This unit contains two rectifier systems which furnish all the d-c voltage necessary for the operation of the transmitter. Fig. 22 shows a view of this unit.

Relay Receiver.—The relay receiver is a superheterodyne designed to operate from a 150-ohm antenna transmission line. Coupled fixed-tuned "transmission line" circuits are used in the input system of the

receiver. These circuits are adjusted to pass a frequency band of 12 megacycles in the range between 280 and 340 megacycles. The oscillator circuit is also of the "transmission line" type. The intermediate-frequency amplifier consists of seven transformer-coupled stages. The second detector circuit is d-c coupled to the automatic volume-control rectifier, so that the automatic volume-control voltage is proportional to the peak value of the incoming video signal, *i. e.*, synchronizing peaks. Provision is made for disconnecting the automatic volume control and using manual volume control if desired. The video-frequency amplifier supplies an output of about 2 volts peak to peak across a 75-ohm line. Figs. 23 and 24 show the

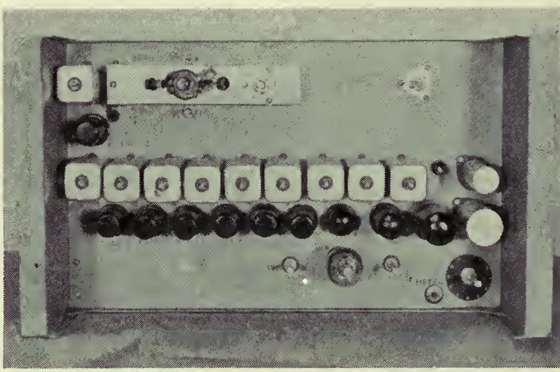

FIG. 23. Ultra-high-frequency relay receiver—front view.

front and rear views of the receiver. The front view of the power supply unit is given in Fig. 25.

PRACTICAL APPLICATIONS OF THE EQUIPMENT

Television programs have been broadcast as a public service during the past year. The telemobile units previously mentioned have been used in many "on the scene" pick-ups and these have almost all been very popular. The pick-up of many potentially interesting programs has been impracticable because of the size, weight, and power requirements of the mobile units. Although the cameras associated with these units can be operated at distances up to 500 feet from the unit housing the control equipment, this in many instances is not sufficient because the control unit can not be placed in an advantageous loca-

tion. The a-c input power, especially the three-phase for the transmitter unit, has frequently been very difficult to obtain.

The new "suitcase" type of portable pick-up equipment therefore greatly increases the program potentialities outside the studio. The size, weight, power requirements, and flexibility of the equipment are such that for the first time program pick-ups aboard airplanes, boats, and automobiles in motion are possible. The program possibilities that the equipment creates are thus evident, for it is obvious that the extension of the television eye to points outside the

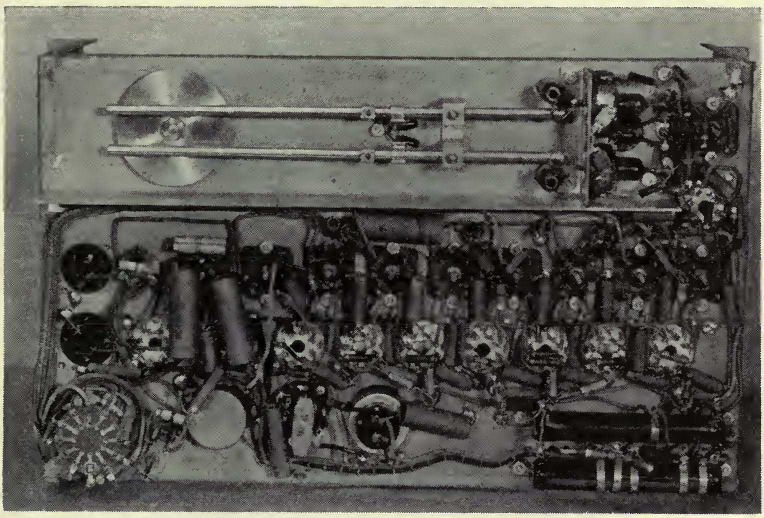

FIG. 24. Ultra-high-frequency relay receiver—rear view.

studio is an even greater boon to television than was the corresponding extension of the microphone in sound broadcasting. The new equipment has recently been used aboard an airplane to pick up scenes of New York and transmit them to Radio City for a program broadcast from the transmitter in the Empire State Building.

It is quite possible to carry the complete pick-up apparatus into any building, amusement park, theater, *etc.*, in order to televise events that are inaccessible to pick-up equipment mounted permanently in a truck. The few kilowatts of single-phase a-c power required for the entire equipment can be obtained in most locations.

Another important application of the new equipment is the televising of regular sound broadcast programs in the studios in which they are normally presented. Although such use does not provide all the flexibility of a studio permanently equipped for television, it does permit a very useful extension of pick-up facilities for certain types of programs.

The portability of the transmitter is a great advantage in remote pick-up work. In many locations it is necessary to erect an antenna on the roof of a building or some other high structure in order to obtain line-of-sight transmission to the receiving point. In the case of a transmitter mounted permanently in a truck, a rather long radio-frequency transmission line is required. The problem of adjusting

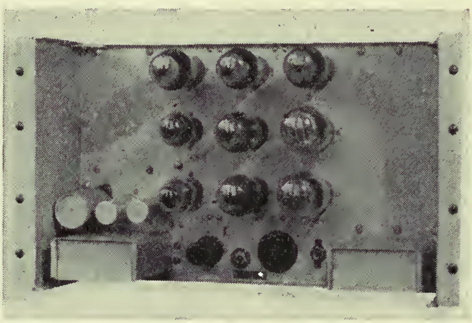

FIG. 25. Ultra-high-frequency relay receiver power-supply unit.

such a line to carry television signals without serious reflections is a difficult one, even in a permanent installation, and for portable or mobile work the difficulties are still greater. The new equipment makes it possible to locate the transmitter on the roof or upper floor of a building so that a short radio-frequency transmission line can be used to the antenna. In this case the transmitter is connected to the pick-up equipment by means of a flexible coaxial cable or other video-frequency line. The transmission of the video-frequency signals over a suitable line presents a considerably less serious problem than the transmission of radio-frequency power over a line of equivalent length.

Acknowledgments.—The authors wish to acknowledge the individual and coöperative efforts of the many engineers who participated in the development of this equipment.

A NEW NEGATIVE CARBON FOR LOW-AMPERAGE HIGH-INTENSITY TRIMS*

W. W. LOZIER, D. B. JOY, AND R. W. SIMON**

Summary.—*A new negative carbon is described which makes possible the extension to low current and short arc length of the high-intensity direct-current carbon arc with copper-coated non-rotating electrodes. Data are given which show that this new negative carbon, known as the "Orotip" C carbon, has made feasible combinations of carbons and burning conditions which bring about significant improvements in the efficiency of production of light from the standpoint of carbon utilization and power consumption. This new negative carbon has practically eliminated carbide tipping and its undesirable consequences. Results are given which show that most of the theaters now using low-intensity carbon arcs have an inadequate level of screen brightness. It is shown that the new combinations made possible by the "Orotip" C negative carbon offer a remedy for this, while at the same time giving a better color quality and maintaining a total operating cost no higher, or only slightly higher, than for the low-intensity combination.*

Since the non-rotating high-intensity d-c carbon arc was introduced about six or seven years ago, it has enjoyed widespread acceptance and has become standard equipment in a majority of the medium-sized theaters. Its simplicity and high efficiency continue to be desirable features and its high output of light of snow-white color has enabled it to meet the ever more critical demands for an adequate level of light of suitable color quality. The rapid growth of motion pictures in natural color has greatly accentuated these demands. However, while the large and medium-sized theaters throughout the country have adopted the high-intensity arc, over sixty per cent of the theaters in this country are still using the low-intensity arc. In addition to a less desirable quality of light for colored motion pictures, many of these theaters are operating with a light-intensity falling far below the minimum brightness recommended for comfortable viewing.

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* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received April 22, 1940.

** National Carbon Co., Fostoria, Ohio.

SCREEN BRIGHTNESS IN THEATERS USING LOW-INTENSITY ARCS

In order to form a mental picture of the screen brightness now being obtained in theaters using low-intensity lamps it is necessary to know the amount of light falling on the screen, the reflectivity of

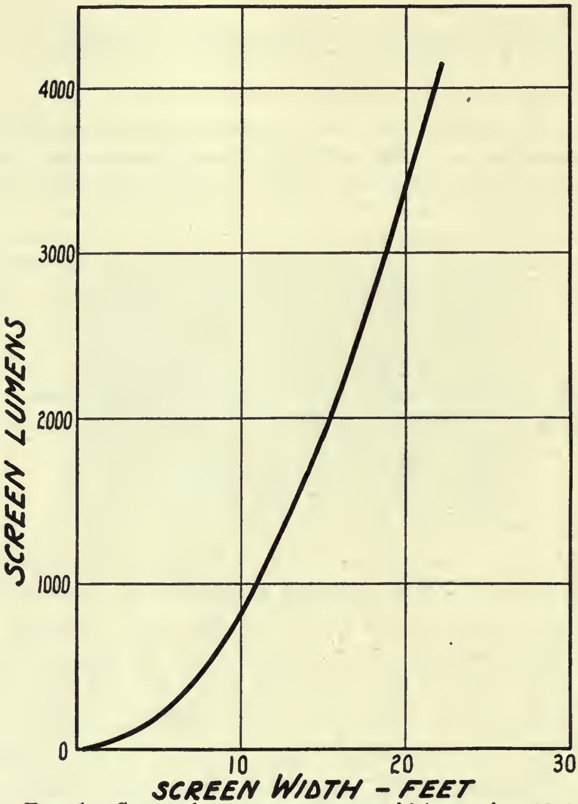


FIG. 1. Screen lumens *vs.* screen width to give 10.5 foot-lamberts center brightness with 75 per cent screen reflectivity and 70 per cent side-to-center screen distribution.

the screen employed, and its size. Reflection characteristics of the screen vary considerably, depending on the type and condition of the screen; however, in the discussion to follow, 75 per cent reflectivity for diffusing screens in good condition has been used.[1] The Recommended Practice of the SMPE for screen brightness[2] calls for 7 to 14 foot-lamberts at the center of the screen without film in the

projector but with the projector shutter running. For purposes of this discussion, the average of these recommended extremes, 10.5 foot-lamberts, will be used. Fig. 1 shows the total lumens necessary to illuminate screens of various widths to a central brightness of this magnitude. The decrease in brightness from the center to the sides

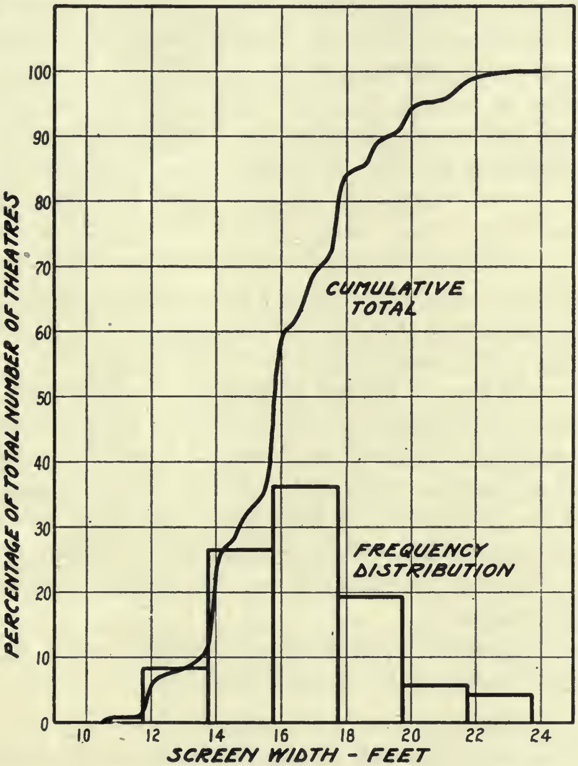


Fig. 2. Survey of screen widths in 122 theaters using low-intensity carbon arcs.

of the screen has been taken as 30 per cent in calculating these values. Had a more uniformly lighted screen been assumed, the lumen values would have been higher.

Tests made in the laboratory and in theaters have indicated that low-intensity lamps and optical systems in good condition can project approximately 2400 lumens of light to the screen without the projector shutter running and without film in the machine. A 90-

degree projector shutter reduces this to 1200 lumens, and reference to Fig. 1 indicates that this amount of light will give a center brightness of 10.5 foot-lamberts or more only with screens 12 feet wide or less.

Previous data[3] on screen sizes in use have not segregated the theaters using low-intensity lamps from those using high-intensity lamps. Therefore during 1939 the National Carbon Company made a survey of the screen sizes in 122 theaters using low-intensity lamps. These theaters were scattered all over the United States, so that it is reasonable to believe that the data are representative. The results of this survey are given in Fig. 2, which shows both the frequency distribution and the cumulative total of the different screen sizes. The screens range from 11 to $23^1/_2$ feet in width, 85 per cent being 18 feet wide or less, while only 5 per cent have a width of 12 feet or less. Therefore this survey indicates that only 5 per cent of the theaters now using low-intensity lamps have sufficient light to illuminate their screens to a central brightness of 10.5 foot-lamberts. As indicative of the remainder, it should be noted that a screen 18 feet wide would have a central brightness of only about 4.5 foot-lamberts with low-intensity arc illumination. It should be realized that these figures throughout are based on favorable conditions of light output and screen reflectivity. Where these conditions are not maintained the light levels are even lower than those indicated.

That there is a decided need for a higher level of screen illumination in theaters now using low-intensity arc illumination does not require further demonstration.

The most important qualifications demanded of a light-source capable of accomplishing the desired result are

(*1*) A higher light output than the low-intensity arc
(*2*) A satisfactory light quality for the projection of colored motion pictures
(*3*) A low cost of operation
(*4*) A satisfactory burning performance

PRESENT "SUPREX" CARBONS

The sizes of "Suprex" carbons most widely used today are the 8-mm positive with the 6.5-mm or 7-mm negative carbon and the 7-mm positive with a 6-mm negative carbon. A 6-mm—5-mm "Suprex" trim was introduced along with the larger sizes but did not attain appreciable usage because the small size of this light-source did not give proper coverage at the aperture with the optical systems

employed, which were designed primarily for the larger carbons. Also this trim gave difficulty from carbide tip formation except when burned at the higher currents and consumption rates.

The 7-mm—6-mm trim, although rated for operation over a current range of from 50 to 42 amperes, when burned below 45 amperes, had much the same limitations as the 6-mm—5-mm trim. Consequently, practically all the usage of "Suprex" carbons has been at currents no lower than this value. At this minimum practical limit of 45 amperes, the 7-mm—6-mm "Suprex" trim gives with an $f/2.5$ optical system approximately 5000 lumens on the projection screen without the shutter running or 2500 lumens with a 90-degree shutter. This value is approximately twice the maximum attainable under favorable conditions with the low-intensity arc.

EFFECTS OF CARBIDE TIP

As mentioned above, when the current with the 7-mm—6-mm trim is reduced below 45 amperes, or correspondingly when the 6-mm—5-mm "Suprex" trim is used in the lower part of its operating range, a coating of rare earth carbide forms on the negative tip. This carbide tip disintegrates forcibly if present during the striking of the arc and causes a shower of sparks. Also when allowed to cool, this carbide tip is a poor conductor of electricity and in some cases becomes insulating enough to prevent restriking of the arc. In addition, during burning, the carbide tip covers the core of the negative carbon, thereby reducing its intended effect of steadying the arc. This frequently results in wandering of the arc and unsteady light on the screen. Usually the carbide tip on the negative carbon builds up over a period of 5 to 10 minutes, thereby changing the characteristics of the arc during this formation period. This may have the effect of requiring more attention to lamp adjustment during the burning of the trim, particularly as regards the position of the negative carbon and the adjustment of feeding mechanism. It thus became apparent that it would be an achievement of considerable importance if the formation of the carbide tip on the negative carbon could be prevented.

In the course of the ensuing experimental work the effect on carbide tip of the various characteristics of the negative carbon and the burning conditions of the arc were studied. It was found, for instance, that carbide tip could be reduced by operating with comparatively long arc lengths and also with high currents, as is the case

with the present method of operating "Suprex" carbons. However, both high currents and long arc lengths make for high power usage and rapid carbon consumption, so that they do not fit in with the goal of supplying an economical combination for the small-sized theater.

Experiments also showed that a reduction of the diameter of the negative carbon would substantially reduce carbide tip. This step, however, would increase the consumption rate of the negative carbon and so is likewise not in harmony with the object of obtaining a carbon trim economical to operate. The solution to the problem came as the result of the development of an entirely new negative carbon. This new negative carbon is known as the "Orotip" C carbon.

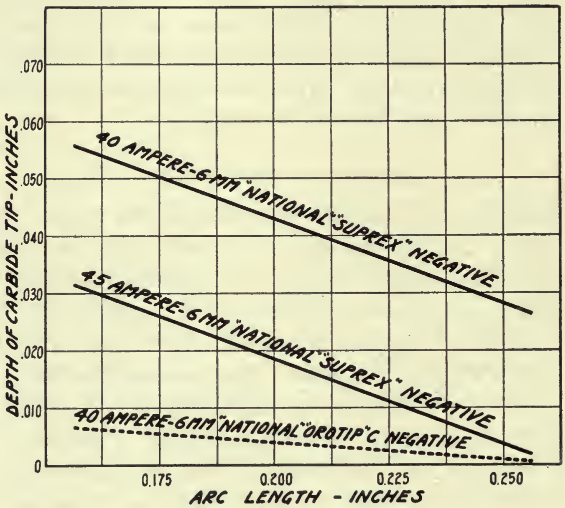


FIG. 3. Carbide tip *vs.* arc length at different currents for 6-mm "National" "Suprex" and "National" "Orotip" C negative carbons with 7-mm "National" "Suprex" positive carbons.

TESTS WITH "OROTIP" C NEGATIVE

When carbide tip occurs to any considerable extent it forms a hemispherical cap over the end of the negative carbon, and in experimental tests the extent of the carbide tip has quantitatively been gauged by noting the apparent depth of this cap. That the "Orotip" C negative carbon has effected a remarkable reduction in carbide

tip is shown by Fig. 3. Here, the depth of carbide tip on the negative carbon is given for both the "Orotip" C and the regular "Suprex" negative for different arc lengths and arc currents. The amount of carbide tip with the "Orotip" C negative under the conditions of Fig. 3 is less than 0.01 inch, which is too small to be conveniently measured with accuracy. It has therefore been estimated by the dashed line in Fig. 3. These results show that to obtain with the

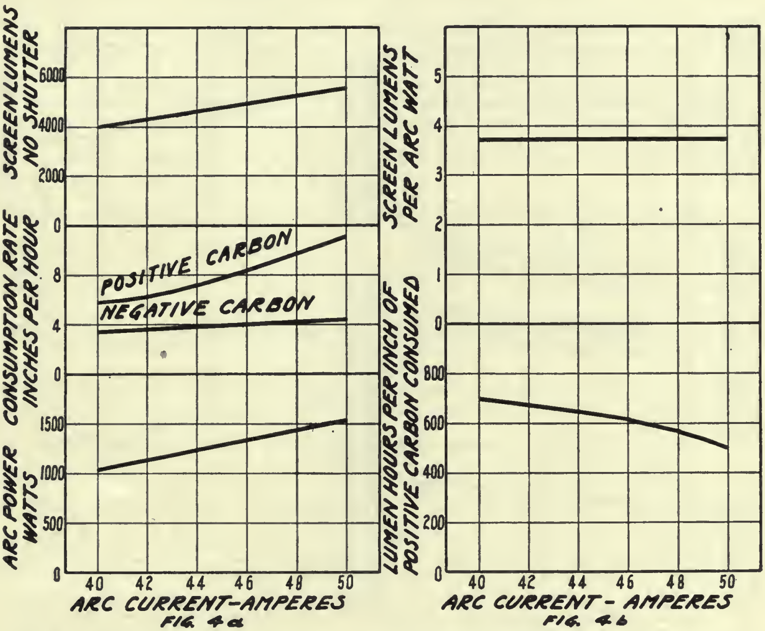


FIG. 4. Burning characteristics of 7-mm "National" "Suprex" positive—6-mm "National" Orotip C negative *vs.* current at constant arc length of 0.175 inch.

"Suprex" negative the same degree of freedom from carbide tip as with the "Orotip" C negative carbon, the current must be kept above 45 amperes or the arc length must be maintained longer than 0.25 inch, as is usual practice with present simplified high-intensity trims. The freedom from carbide tip shown by the "Orotip" C carbon has made feasible combinations of carbons and burning conditions hitherto considered impracticable. As shown in Fig. 3 it is possible to operate the "Orotip" C at currents as low as 40 amperes and arc lengths as short as 0.15 of an inch, without encountering an

undesirable amount of carbide tip. The employment of these low currents and short arc lengths brings with it worthwhile improvements in efficiency which will now be described.

IMPROVEMENT IN ARC EFFICIENCY

Using the 7-mm "National" "Suprex" positive with a 6-mm "National" "Orotip" C negative carbon, laboratory tests have been

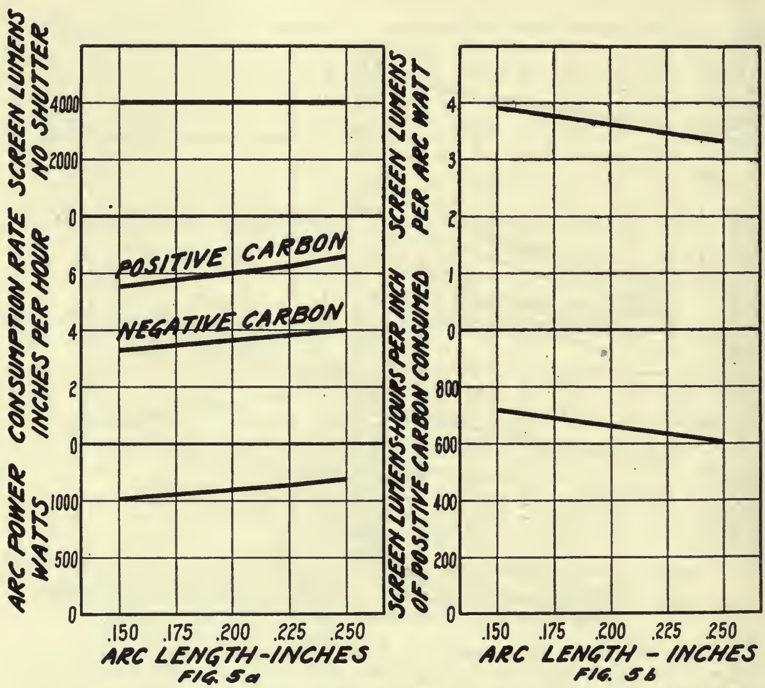


FIG. 5. Burning characteristics of 7-mm "National "Suprex" positive—6-mm "National" Orotip C negative *vs*. arc length at constant current of 40 amperes.

made on the various arc characteristics at different currents and arc lengths. Fig. 4 shows the results obtained with this trim at a constant arc length of 0.175 inch in a lamp having a 7.5:1 magnification mirror, which had approximately the same speed as the $f/2.5$ projection lens employed. As shown in Fig. 4(a), when the current is reduced from 50 to 40 amperes, the screen light, carbon consumption rate, and the arc power all decrease.

There are two quantities which relate to the efficiency of the arc.

One of these describes the lumens projected to the screen in terms of the electrical power consumed, and the other describes the lumen-hours projected to the screen in relation to the amount of positive carbon consumed. As shown in Fig. 4(*b*) the amount of screen lumens per arc watt remains essentially constant when the current is reduced from 50 to 40 amperes, so there is no change in efficiency of utilization of electrical power. However, this same figure shows a gain of 40 per cent in the total amount of light-energy obtained from a unit length of positive carbon. This light-energy, measured in lumen hours per inch of positive carbon consumed, increases from 500 at 50 amperes to 700 at 40 amperes. This gain in efficiency of carbon utilization at the lower current is made practicable by the use of the "Orotip" C negative carbon which permits low-current operation without appreciable carbide formation.

Fig. 5 shows the results of tests made with the same lamp and optical set-up as described for Fig. 4, but in these latter tests the arc current was maintained at 40 amperes and the arc length was varied from 0.15 to 0.25 inch. This reveals further important gains in efficiency through operation at short arc lengths. One very important fact illustrated in Fig. 5(*a*) is that the screen light is not altered by operating at arc lengths as short as 0.15 inch. This feature has been recognized for some time[4] but was not practicable to use because of the formation of carbide tip at short arc lengths. Fig. 5(*a*) shows also that reduction of the arc length from 0.25 to 0.15 inch results in a decrease of 15 per cent in both carbon consumption and arc watts. As shown in Fig. 5(*b*), this results in a 15 per cent improvement in efficiency of utilization of both power and carbon for producing screen light.

To summarize, therefore, it has been shown that the low current and short arc length operation made possible by the "Orotip" C negative has resulted in a marked improvement in the efficiency of production of light from the standpoints of both carbon utilization and power consumption.

The foregoing discussion has pertained chiefly to the 7-mm—6-mm trim of carbons. Similarly, the "Orotip" C negative carbon makes possible the use of a combination of smaller carbons at low currents and short arc lengths without the appreciable formation of carbide tip.

The effects of the characteristics of the power source on the stability of the non-rotating high-intensity d-c arc have been fully discussed in

TABLE I

Comparison of Various Trims

Carbon Combination	Amperes	Arc Volts	Arc Watts	Screen Lumens No Shutter*	Screen Lumens per Arc Watt	Width of Diffusing Screen of 75% Reflectivity** Minimum Recommended Brightness, 7 Ft-Lamberts	Mean of Recommended Range of Brightness, 10.5 Ft-Lamberts	Maximum Recommended Brightness, 14 Ft-Lamberts
12-mm—8-mm "National" "SRA" low intensity	32	55	1760	2400	1.4	14.7 feet	12.0 feet	10.4 feet
6-mm "National" "Suprex" positive—5-mm "National" "Orotip" C negative	30	27.5	825	3300	3.6–4.0	17.2	14.0	12.1
7-mm "National" "Suprex" positive—6-mm "National" "Orotip" C negative	40	27.5	1100	4000–4300		19.3	15.7	13.6

* Values measured with an $f/2.5$ lens.

** Assuming 90° projector shutter and 70% side to center screen light distribution.

a previous article.[4] In that discussion it was shown that a low-voltage power source with only a slightly falling volt-ampere curve at the arc gave a more stable arc and steadier screen light than a high-voltage power source with a large proportion of ballast. Likewise in that earlier paper the stabilizing effect of supplementary magnetic flux on the arc was explained. Both these factors, the characteristics of the power source and the use of supplementary magnetic flux, are necessary to obtain the best stability with the arcs just described.

The feeding mechanism must be capable of feeding the carbons uniformly and maintaining the short arc gap between the electrodes. With both the 7-mm—6-mm trim and the 6-mm—5-mm trim at low currents and short arc lengths, the light-source is smaller than is the case with the sizes of carbons and currents ordinarily used in "Suprex" lamps. The magnification of the mirror collecting the light must be sufficient to cover the motion picture aperture. New lamps on the market have taken account of this and are equipped with mirrors having the higher magnification ratio.

THEATER APPLICATION

Table I shows data on the 6-mm—5-mm and 7-mm—6-mm trims using the "Orotip" C negative carbon and also shows comparable data on the 12-mm—8-mm low-intensity trim. The screen lumens per arc watt for these high-intensity trims are from $2^1/_2$ to 3 times as great as for the low-intensity arc. This is an important feature, and contributes to the achievement of a total operating cost with these high-intensity trims no higher or only slightly higher than for the low-intensity combination despite the fact that they give a much greater amount and better color of light.

The last three columns of Table I show the size of a diffusing screen of 75 per cent reflectivity which can be illuminated by these light-sources to center brightness values of minimum (7 foot-lamberts), mean (10.5 foot-lamberts), and maximum (14 foot-lamberts) recommended screen brightness. The results of the survey on screen sizes shown in Fig. 2 indicate that the low-intensity carbons and lamps deliver enough light to furnish desirable screen brightness for only a small percentage of the theaters now using this combination. These new low-amperage high-intensity 6-mm—5-mm and 7-mm—6-mm carbon combinations (together with the regular "Suprex" combinations for the largest screens) extend to the theaters now using low-

intensity arcs a practicable means of increasing their screen brightness to the recommended range and, in addition, give them the same desirable color quality of light as the theaters now using the high-intensity carbon combinations.

REFERENCES

[1] COOK, A. A.: "A Review of Projector and Screen Characteristics and Their Effects upon Screen Brightness," *J. Soc. Mot. Pict. Eng.*, **XXVI** (May, 1936), p. 529.

[2] "Revisions of S.M.P.E. Standards Proposed for Adoption by the Society," *J. Soc. Mot. Pict. Eng.*, **XXX** (Mar., 1938), p. 257.

[3] "Report of the Projection Practice Committee," *J. Soc. Mot. Pict. Eng.*, **XXX** (June, 1938), p. 645.

[4] JOY, D. B., AND GEIB, E. R.: "The Non-Rotating High-Intensity D-C Arc for Projection," *J. Soc. Mot. Pict. Eng.*, **XXIV** (Jan., 1935), p. 49.

DISCUSSION

MR. EDWARDS: If we maintain a closer arc with the new "Orotip" C, with consequently less cost per lumen, then why not increase the size to 8-mm, 60 amperes?

MR. WILLIFORD: All the improvements can not come out at once. We are aware of the industry's desire for greater screen illumination, and have been working toward that goal for many years. Intensities have steadily been going up. The question of screen light standards has been raised, and the Society has been loath to recommend the standards that we think we ought to have until we have optical systems, light-sources, and screens that will give us those standards. There is no reason why everyone can not today have 10 foot-candles on his screen.

MR. RICHARDSON: Provided the screen width does not exceed 18 feet.

MR. WILLIFORD: He can have it, even so. With developments now under way he can go to higher intensities on any screen. It has been a matter of development in various channels, including the matter of lens surfaces. With improvements in optical systems, screens, and light-sources we are making it possible to get the levels of screen illumination the industry believes it should have. I can not promise how soon some of these later developments will enter the larger theaters, but they are definitely in the offing, and the results today are exceedingly promising.

MR. GRIFFIN: The Standards Committee has already revised the previously recommended screen brightness, I believe.

MR. JOY: The recommended practice at the present time is 7 to 14 foot-lamberts at the center of the screen. That means, in terms of foot-candles, with a 75 per cent reflection factor, about 9 to 18 foot-candles. For an average of, say, 10 foot-candles, we should have about 12 or 13 at the center and falling off toward the edges.

MR. MCAULEY: If we take into account the increased projector shutter speeds; the use of 70-degree shutters instead of 90-degree; the widespread use of high-intensity arcs instead of low-intensity or any of the neutral-cored carbons; the increased efficiency of the optical systems—that is keeping pace pretty well with the demand that colored pictures have created for increased illumination.

COLOR THEORIES AND THE INTER-SOCIETY COLOR COUNCIL*

H. P. GAGE**

Summary.—*Thanks to intensified study of color by scientists of the National Bureau of Standards, of the Agricultural Marketing Service of the U. S. Department of Agriculture, of the Committees of the American Association of Railways, glass manufacturers, dye manufacturers, paint and ink manufacturers, the American Pharmaceutical Association, and photographic manufacturers and the stimulation of the motion picture industry, the theories of color have been put in shape and tied together with extensive data on the color vision of many observers so that a workable engineering evaluation of colors, a scientific system of naming them, and practical means of producing them to exact specification is now available and is ripe for presentation not only to learned societies but to the general public.*

Colored lights are subject to spectrophotometric measurement and by means of the ICI (International Commission on Illumination) data can be interpreted in terms of luminosity and the x and y coördinates (or map) defining chromaticity.

In these terms are being defined the color limits for railway signal colors, also all standard Atlases of Color such as the Maertz & Paul Dictionary of Color, the Munsell Book of Color, and, it is hoped, the next standard set of colors of the Color Card Association of the U. S. used by all manufacturers of clothing and other things in which standardization of manufacture in spite of rapid changing styles is an economic necessity.

The next edition of the Pharmacopoeia and of the National Formulary, sponsored by the American Pharmaceutical Association, will use the system of color names developed and recommended by the Inter-Society Color Council in coöperation with the National Bureau of Standards to describe the normal appearance of all drugs and chemicals. A shorthand method of describing the spectrophotometric analysis of color filters for theater spot and floodlights in the form of a seven digit number has been devised for commercial specification of this material.

The Inter-Society Color Council is made up of 74 delegates appointed by 11 member societies, and 67 individual members. It functions as a joint committee on color of the member societies favored with advice of the individual members. The Council issues News Letters in mimeograph form to its members. They contain information of progress in color work, notices of important color publications, the activities of the Color Council and notices of its planned meetings. The Council sponsors meetings with the member societies on the subject of color. Such joint meetings have been held with the Optical Society of America, the Technical Association of

* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received June 14, 1940.

** Corning Glass Works, Corning, N. Y.

the Pulp & Paper Industry (T. A. P. P. I.), and the American Psychological Association. A joint technical session on color will be held at the annual convention of the Illuminating Engineering Society this fall and also with the American Society for Testing Materials at its 1941 spring meeting to be held in Washington.

The Society of Motion Picture Engineers has become a member of the Intersociety Color Council, and has appointed as its three voting delegates to the Council Messrs. R. M. Evans, *Chairman*, G. F. Rackett, and T. Bowditch.

It is fitting that the Society of Motion Picture Engineers do this as the exhibition of motion pictures has from its rather early days used color as far as possible to enhance its artistic appeal. The hand-colored French films were, as I remember them, as beautiful as any now produced by the modern processes, but made at a cost which would be considered prohibitive. About 1910 when I first became a serious student of motion pictures, my father and I were given a well worn copy of a colored film to experiment with, so that color in films can hardly be considered new. The tinting and toning of films were frequently resorted to and the lurid colors of fire scenes were well known. Sound also had been applied as a curiosity by synchronized records. We do all these things now in immeasurably greater volume, and, we believe, with greater skill but by methods already outlined by the pioneers.

For the outline of the theories of color vision we go back to Thomas Young[1] who proposed that three primary sensations of the eye accounted for all the colors we see; to Clerk Maxwell who proved this to be the case by projecting simultaneously on the screen three-colored pictures taken with three color filters, red, green, and blue, thereby producing a recognizable reproduction of colored objects. The exact behavior of the eye to colors was outlined by Helmholtz and studied by König and Dieterici.[2] It is to the late Frederick E. Ives,[3] for a long time a member of the Society and now on our Honor Roll, that we owe the methods, first, of halftone engravings so universally used in all printed illustrations, and later of demonstrations of methods of three-color photography, which he greatly improved with the availability of color-sensitive emulsions. He also developed methods of producing colored motion picture films. His work in this field stimulated others and greatly accelerated the attainment of the present level of achievements in color. His son, Dr. Herbert E. Ives, an accomplished student in this field, has demonstrated some of the early methods of television to this Society.[4] Of the achievements of

our fellow members, Dr. C. E. K. Mees and Dr. L. A. Jones, we are all aware. Dr. L. T. Troland, who at one time was a member of this Society and before his death was connected with the Technicolor Corporation, was a deep student of the psychology of color, and was the author, after due collaboration with others, of the 1920–21 Colorimetry Report of the Optical Society of America,[2] which is the cornerstone upon which is founded the modern scientific study of color. Our Society has listened to reports on color by Dr. K. S. Gibson,[5] of the Colorimetry Division of the National Bureau of Standards and by Dr. D. B. Judd,[6] also of the same Division. Both papers, incidentally, received the Journal Award of the Society in their respective years.[7,8]

Of the members of our Society who are also members of the Colorimetry Committee of the Optical Society we find Dr. L. A. Jones, *Chairman*, Dr. H. P. Gage, and Prof. A. C. Hardy.

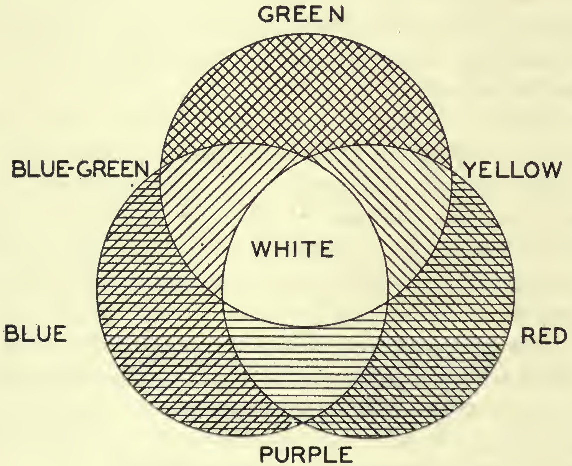
These members, in addition, are already delegates to the Inter-society Color Council, and represent either the Optical Society of America or the Illuminating Engineering Society. Besides these of our members we find as a delegate to the Council Mr. W. F. Little.

I hope I have indicated how intimately some of our members have been identified with the study of color. Before finishing the discussion of the Intersociety Color Council and its activities I wish to say a word about color theories and how they may be worked into the practical problems of the motion picture engineer.

As has already been pointed out, three primary colors, or sensations suitably combined, are sufficient to account for all the colors we can perceive. Demonstrations have repeatedly been presented to this Society to illustrate the theory of color mixture and to demonstrate that one and the same theory serves to clarify both the additive and the subtractive processes for the projection of colored pictures. An excellent presentation of this subject was recently published by Dr. D. L. MacAdam;[9,10] also by J. A. C. Yule.[11]

When three projectors are used, one of which produces a red field, one a green field, the other a blue field in properly balanced amounts, all three projecting slightly different pictures of the same subject, we find the following phenomena: Before the three projected spots are brought into register, we see red, green, and blue (Fig. 1) areas. Where the red and green overlap we get yellow; where the green and blue overlap we get blue-green; where the blue and red overlap we get a red-purple, or magenta. Where all three

overlap, if properly balanced, we get white. If, now, each projector contains a suitable positive, made from a negative taken through the same color-filter, combined images give a life-like representation in color of the scene or objects photographed. This is the principle used in the Kodacolor process. Instead of presenting the three pictures simultaneously they may be presented alternately, and persistence of vision will blend the colors and action. Flicker enters as a complication when using three colors, so two complementary colors,



Additive Method

FIG. 1. Illustrating the additive method of color mixture. Spots from three separate lanterns are red, green, and blue. Where the red and green overlap is yellow; where the green and blue overlap is blue-green or cyan; where the blue and red overlap is purple or magenta; where the three overlay is white.

red and blue-green, have ordinarily been used, as in the Prizma process.

The subtractive process has frequently been demonstrated by the triangular diagram shown in Fig. 3. A lantern-slide in this form was constructed by using unmounted Wratten filters, Nos. *44*, *32*, and *12*.

Across the bottom is a strip of magenta-colored gelatin film. The dye in it absorbs only green, transmitting both blue and red. On the right side is a yellow film, absorbing only blue, and transmitting red and green. On the left is a blue-green film, absorbing only red and transmitting blue and green.

Where two of these strips overlap, as at the left and right corners, each strip removes its typical absorption band, and what passes through both, is what is left. Thus where the minus green and minus red overlap, what remains is blue, which both strips transmit. Where the minus green and minus blue overlap, only red is transmitted. Overlapping minus blue and minus red leave only green,

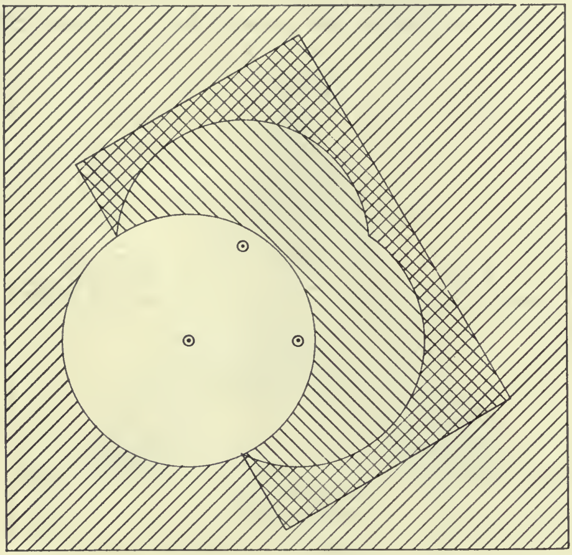


FIG. 2. A lantern-slide for producing Fig. 1 is made by overlapping three gelatin filters, each cut as indicated in the right-hand sloping diagonal line. The three filters are fastened to a glass slide. On the cover-glass is fastened a tinfoil mask of the shape indicated by the left-hand sloping lines. While the effect is accomplished by means of the subtractive method, the appearance is the same as is secured by the additive method.

and in the center where each film takes its particular toll of white light, after removing red, green, and blue, there is nothing left, so we get black. This principle is used in the Kodachrome process, where three pictures separated by clear gelatin layers have been produced in colors essentially like those illustrated in the lantern-slide.

The phenomena described can be more clearly illustrated by a spectrum analysis of the colored gelatins used to make the slide. There are many ways of doing this, such as by curves, by photo-

graphs, by observations through a pocket spectroscope, or by projection of the spectrum on the screen. The projection of spectra often requires such bulky apparatus that one hesitates to transport it. For the present purpose it will be demonstrated by a bright-line transmission grating prepared by Professor R. W. Wood of the Johns Hopkins University. The peculiarity of this grating is that it concentrates most of the energy in one of the first-order spectra. All the other orders of spectra are present but are less bright. The

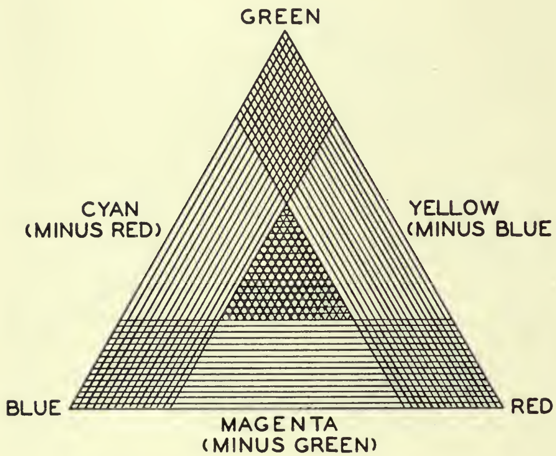


FIG. 3. The subtraction method of color mixing. Three strips of colored gelatins are laid between two coverglasses. These are minus red or cyan, minus blue or yellow, and minus green or magenta. Where these overlap, two by two, is seen red, green, and blue. Where all three overlap no light gets through, leaving a black triangle.

gratings with about 5000 lines per inch project this first-order spectrum on the normal picture area.

First a cardboard with a slit is put into the slide-holder of the lantern (Fig. 5). This is made stepwise to produce narrow and wide slits. The grating is placed over the projection objective so that on the screen, wall, ceiling, and floor are seen all the diffraction spectra. The first-order spectrum will fall within the normal picture area on the screen. In each spectrum we see three colors, red, green, and blue. While by careful scrutiny of narrow strips of this spectrum it is possible to isolate orange, yellow, blue-green, and an extreme

violet, which appears as a slightly bluish red, and while a delicate thermopile will detect radiant energy beyond the red, which is known as infrared, a photographic plate will show exposure beyond the violet, which is called ultraviolet. Fluorescent materials will be excited and glow in this region. For purposes of our color theory the three easily seen bands, red, green, and blue suffice. There is an important minority of observers who see colors differently owing to a different

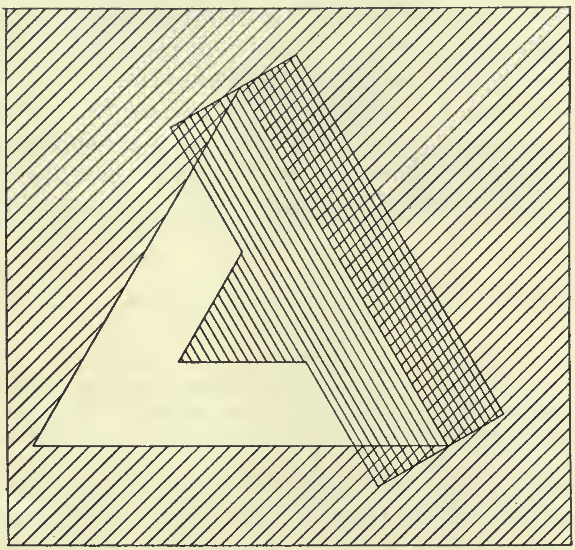


FIG. 4. Construction of Fig. 3. The three gelatins are cut into strips with a triangular extension as illustrated by the right-hand sloping lines. These strips are fastened to one coverglass, and a tinfoil mask as indicated by the left-hand sloping lines is fastened to the other glass, giving the appearance shown in Fig. 3.

type of color-sensitivity of the eye. These are usually treated as special cases and their study has added much for the theories of color vision. Dr. Judd has given us a paper on this subject.[6]

In front of the lantern objective and grating is now placed a piece of didymium glass, which has a narrow absorption band in the yellow and other narrow lines in the green. Where the slit is also narrow the spectra exhibit these narrow absorption lines. Where the slit is wide, the spectra appear brighter but the narrow absorption bands are wiped out. This illustrates the importance of a fairly narrow slit in

all spectroscopic analysis, and the eternal conflict between intensity and purity or resolution in spectroscopic research.

A photograph of the projected spectrum can be made as a permanent record, or some type of sensitive measuring and recording instrument can be moved across the spectrum to draw a curve such as a curve between wavelength and transmission of a filter or reflection from a colored surface (Fig. 9). The photoelectric spectrophotometer devised by Prof. A. C. Hardy and manufactured by the General Electric Company is an outstanding example of how accurately and expeditiously such curves can be made for use in analyzing colors.

If small pieces of the three gelatin filters used in the previous demonstration are placed over parts of the slit, we see (Fig. 6) that corresponding to the clear parts of the slit there is a complete spectrum, but corresponding to those parts of the slit covered by the colored gelatins it is apparent that from the complete spectrum of white light,

Slit

FIG. 5. Slit having various openings, cut from cardboard. This should be made to appear in the lower portion of the picture area.

the blue-green gelatin (*No. 44*) has removed the red, the magenta (*No. 32*) has removed the green, and the yellow (*No. 12*) has removed the blue. If in front of the slit we use the same gelatins and overlap them a little, we see the same phenomena as illustrated in the (Fig. 7) triangle slide: namely, in the overlapping parts there is transmitted only blue, red, or green.

For black-and-white illustrations photographs made with the wedge spectrograph have been used. These are shown in Dr. Mees' book, "An Atlas of Absorption Spectra"[12] and the Eastman pamphlet[13] on Wratten light-filters. The instrument is well adapted to illustrate the spectral regions to which emulsions are sensitive.

With the Hardy spectrophotometer now available, most of such data can be presented in curve form and this seems to be (Fig. 9) preferred by most people.

INTERPRETATION OF SPECTROPHOTOMETRIC CURVES

Colored lights are subject to spectrophotometric measurement and by means of the ICI (International Commission on Illumination)

data can be interpreted in terms of luminosity and the x, y coördinates (or map) defining chromaticity. It is to be clearly understood that not only must the spectral transmission or reflection of the filter or colored object be considered but also the spectral emission of the original light-source. To give a definite place on the diagram to a color-filter one must assume a definite light-source. The color-mixture diagram may be regarded as a map on which any color may be

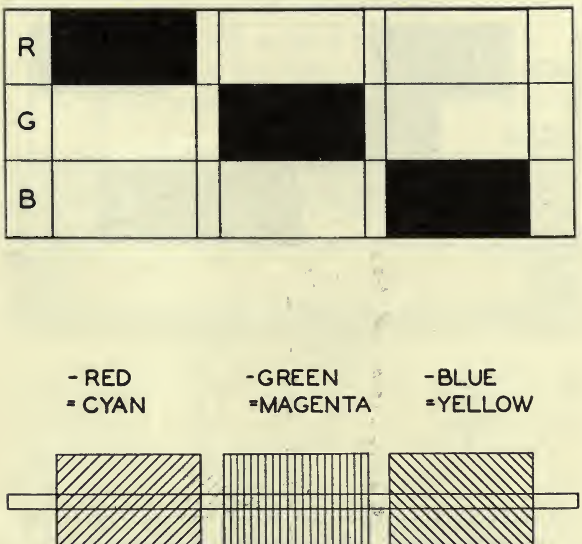


FIG. 6. Lantern-slide with slit, which may be cut in tinfoil, over which are placed the gelatin filters. When the bright-line diffraction grating of 5000 lines per inch is placed over the projection projective, the first-order spectrum should appear within the picture area. The black spaces indicate the absorbed region of the spectrum.

represented by its position, and this position compared with the positions of other colors will give an idea as to the degree of similarity of the respective colors and to the way in which they differ. In the case of a geographic map the locations of cities, mountains, and rivers are designated by their coördinates, known as latitude and longitude, whereby these locations can be placed properly on the map and their relation to each other illustrated. There are several types of maps, such as the spherical type or globe; the flat representations of a globe, such as Mercator's projection, with its enormous distortion of the

size of the polar regions, notably Alaska and Greenland; and the types in which areas are correct but angular distortion occurs. In all cases, however, a web of latitude and longitude lines is first drawn and the geographic features are located by their measured coördinates. The original determination of the coördinates is a technical matter well known in principle by astronomers, navigators, and surveyors.

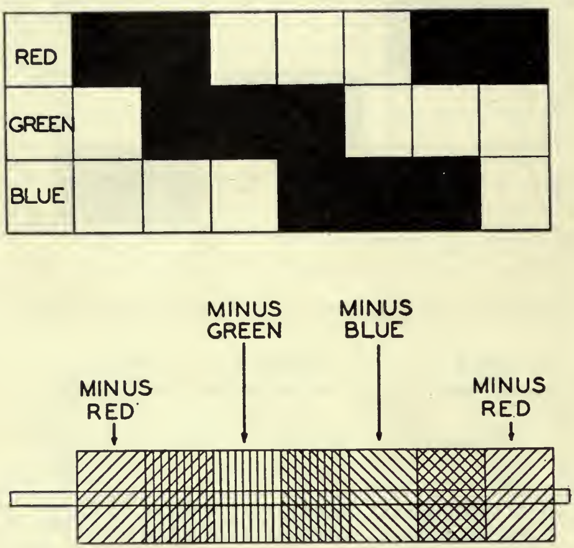


FIG. 7. Slit in front of which have been placed overlapping color-filters. Where two filters overlap only the color transmitted by both will show in the spectrum.

With the ICI mixture diagram and coördinate system here illustrated, the coördinates are designated by x and y. The determination of the values of x and y of a given color for the ICI Standard Observer is again a technical matter. No simple meaning can be given to values of x and y, and until the whole process of color analysis has been worked through and several other methods of color representation have been studied, the full advantages of this particular ICI system can not be appreciated. As in the various flat representations of the globe, so in this color map there is considerable distortion. The diagram does, however, illustrate the relation of the different

colors to each other so that this relationship may be made apparent to anyone.

To describe the attributes of color four technical terms are used and the meanings of these terms must be clearly understood before one can make much progress in understanding the subject or in reading the technical literature. These terms are:[2]

Brilliance.—This refers to the intensity of the luminous sensation produced. The difference between the appearance of a bright light and a dim light is a brilliance difference. (Lightness is the word that applies to the black-and-white series of surface colors.)

Hue.—The hue of a color not neutral (gray) is the attribute that permits it to be classed as reddish, yellowish, greenish, bluish, *etc.*

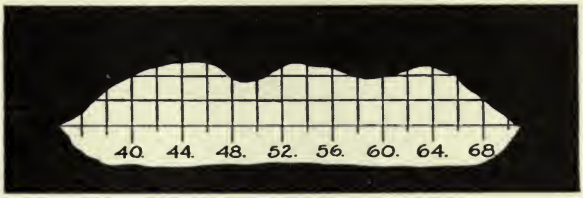


FIG. 8. Appearance of photograph made with wedge spectrograph. The short-wavelength end is limited by the transmission of the instrument. The long-wavelength end and the uneven top are produced by the limit of light-sensitivity of the emulsion.

Saturation.—This is the attribute of all colors possessing hue, which determines their degree of difference from neutral (gray).

Chromaticity.—This term is used to designate the properties of color not connected with brilliance; that is, it combines the attributes of hue and saturation. It is this property of color that is illustrated by the diagram.

The element of saturation is shown by the distance from the white point of the diagram near its center. It will be observed that those colors which are closest to the center of the diagram appear pale or washed out. They differ but little from white and are said to have low saturation.

Those colors farthest from the center appear most vivid and are said to have high saturation. The pure colors of the spectrum have the greatest possible saturation for a given hue. It will be noted, however, that the most vivid yellows and greens nearest the spectrum line are not as saturated as are the extreme blue and red.

Hue is illustrated by the direction from the center of the diagram in which the color is to be found. In one method of color specification the hue is defined as the wavelength of the spectrum which the color most nearly resembles.

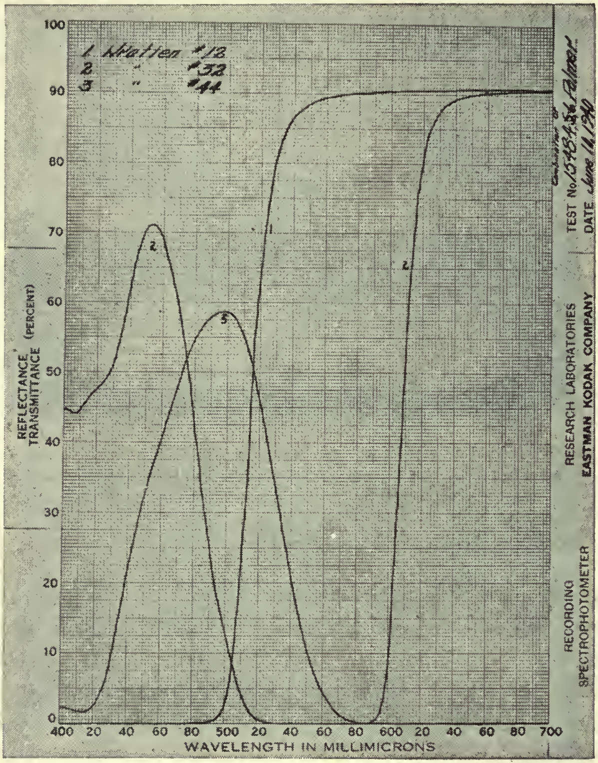


FIG. 9. Spectral curves produced by the Hardy spectrophotometer for the three filters described.
(*1*) Wratten filter No. *12*, minus blue or yellow.
(*2*) Wratten filter No. *32*, minus green or magenta.
(*3*) Wratten filter No. *44*, minus red or cyan.

This serves excellently for red, yellow, and blue signal colors which lie close to the spectrum line. For the greens, none of which lie near the spectrum, considerable difficulty is encountered with such a specification, as these colors do not closely resemble any portion of the pure spectrum.

Measurement of color, or, more properly, measurement of the color stimulus, depends upon three factors:

(*1*) A knowledge of the light-source under which the colored objects are viewed. The two general types of illuminants most often used are:

(*a*) *Daylight.*—For this the spectral energy distribution is usually assumed as that given in the ICI tables for illuminant *C*.

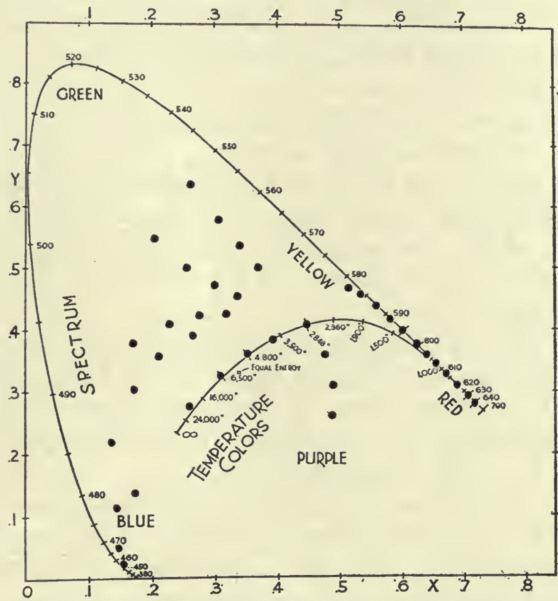


FIG. 10. Color-mixture diagram in accordance with the 1931 ICI Standard Observer and Coördinate System. A copy of this diagram with colored glasses inserted in the openings indicated was prepared for demonstration at the 1939–1940 New York World's Fair.

(*b*) *Artificial light.*—The distribution is usually assumed to be that of a complete radiator or black body at 2848°K and is called ICI illuminant *A*. This corresponds to a gas-filled tungsten lamp of moderate size operated at rated voltage. Other special illuminants can be used provided their spectral distribution is known.

(*2*) The transmission of colored glasses or the reflectance of colored objects for the different portions of the spectrum.

(*3*) The sensitivity of the observer's eye for the different spectral regions. This differs for each individual. A general average for a

reasonable number of normal observers was made after considerable research and the results recorded in tables for the ICI Standard Observer. Observers obviously color-blind were excluded from this general average but have received considerable study as interesting special cases contributing to our knowledge of color vision.

The color vision of the Standard Observer is defined in a table giving three values for each wavelength in the spectrum, designated as $\bar{x}$, $\bar{y}$, and $\bar{z}$. Values of $\bar{y}$ by themselves indicate also the relative luminosity of the various parts of the equal-energy spectrum, the most luminous portion being at a wavelength of 555 $m\mu$. This function is sometimes called the sensitivity curve of the eye; but taken alone refers only to the brilliance aspect of color. The values of $\bar{x}$ and $\bar{z}$ are in the same proportions compared to $\bar{y}$ as are the x and z values compared to y for the given wavelength in the spectrum.

The computations are too involved to be described here, even briefly, and, as the entire subject can be found adequately treated in any one of the several places given below, reference is made to the original literature.

(*1*) The official publication of the sensitivity of the eye of the 1931 ICI Standard Observer is to be found in the Commission Internationale de l'Eclarage,[14] Comptes Rendu des Seances in five resolutions which officially cover the adoption of the particular values describing the ICI (or CIE) Standard Observer.

Resolution *1* refers to the ICI hypothetical observer to be known as the 1931 ICI Standard Observer referring to three homogeneous stimuli of wavelengths 0.700μ, 0.546μ (the green mercury line), and 0.4358μ (the blue mercury line), and expresses the results for the Standard Observer in a table.

Resolution *2* is a description of three standard illuminants:

(*A*) a gas-filled lamp operated at a color-temperature of 2848°K.

(*B*) and (*C*) are energy distributions corresponding to approximate color-temperatures of 4800°K and 6500°K. Values are also given in a table which is part of the resolution.

Resolution *5* covers the ICI coördinate system in which the color-sensitivity of the same Standard Observer is expressed in accordance with a table which is also included in the specification.

(*2*) The first article on the ICI system which includes computational forms is by T. Smith and J. Guild,[15] published in the Transactions of the Optical Society (of England). This article is divided into a description of the five resolutions adopted by the International

Commission on Illumination (ICI) otherwise known as the Commission Internationale de l'Eclarage (CIE).

(*3*) Deane B. Judd,[16] "The 1931 ICI Standard Observer and Coördinate System for Colorimetry." Publication[16] in an American journal covering tables for the same ICI Standard Observer, giving detailed directions for computing the coördinates x and y for a given light-source and a color-filter whose spectral transmission is known. It also describes methods of determining the dominant wavelength and colorimetric purity when the x and y coördinates are known, and describes methods of converting the ICI coördinate system into other systems.

(*4*) K. S. Gibson and Geraldine K. Walker,[17] Signal Section Proceedings, American Railway Association: This is one of a series of reports illustrating how this system may be used for defining the color and transmission of railway signals and the signal glass specifications so prepared are intended to serve as a model for all exact color specifications.

(*5*) Arthur C. Hardy,[18] Handbook of Colorimetry: This book contains tables for the luminosity function and the other two sensation elements for a greater number of decimals interpolated for each millimicron. It also has tables for and illustrates another method of calculation from the spectrophotometric curve known as the selected ordinate method. Charts are given for determining dominant wavelength and purity from the x and y coördinates.

When the railway signal engineers decided upon the color limits within which all colored glass for railway signals had to be supplied, the standard limits were accurately defined in terms of the ICI system.[17] The standard atlases of color, such as the Maertz & Paul Dictionary of Color, the Munsell Book of Color, and it is expected the next standard set of colors of The Textile Color Card Association of the United States, will also be defined according to this same ICI diagram.

After studying the 1931 ICI system one would naturally surmise that there must have been some fairly useful methods of color specification prior to 1931. What were they? One of the most completely thought out of these systems resulted from the efforts of Professor A. H. Munsell of Massachusetts Normal Art School, an artist but also a most versatile individual whose grasp of many subjects reminds us of the diverse activities of Leonardo De Vinci. Munsell devised a system of arranging colors in the form of a color solid

whose study as received at third or fourth hand has permeated the art systems of even the elementary schools. Further study at first hand is to be recommended. The son, Mr. A. E. O. Munsell, devoted much time and considerable treasure in further amplifying the color system and secured the assistance of a distinguished group of scientifically trained people in making exact studies of colors. Among other results a series of colored papers were prepared which conformed as nearly as possible with the theoretical requirements of the color system and illustrate equal spacing of hue, lightness, and saturation of colors as determined by the direct observation of several trained individuals.

These papers, of remarkable uniformity and permanence, are made commercially available by the Munsell Color Company, Baltimore.[19] A series of charts in which are collected these color samples is called the Munsell "Book of Color."

A typical series of samples or color chips sent to the Massachusetts Institute of Technology has received spectrophotometric analysis by Glenn and Killian[20] on the Hardy automatic spectrophotometer, and complete color analysis in accordance with the ICI method is available to interested persons. It is hoped that before long the results will be published. Owing to the meticulous care in the original painting of the color samples to secure accuracy, uniformity, and permanence, their subsequent storage and painstaking methods of distribution, coupled with the measurements made upon typical samples, they have proved to be the best stepping stones for the preparation and preservation of other color standards.

Further studies of color and even of a possible re-spacing of the Munsell colors is now in progress, sponsored by the Colorimetry Committee of the Optical Society of America. All the members of the Subcommittee working on this problem are active delegates of the Inter-Society Color Council.

Another atlas, the Maertz and Paul Dictionary of Color, having printed charts in many colors, is available. One main purpose in preparing this atlas was to illustrate as many as possible of the vast array of color names that have accumulated through the ages. Many of the color samples have been analyzed as far as possible and are now expressed in terms of the Munsell system and can, therefore, be expressed in terms of the ICI chart.

The U. S. Pharmacopoeia and the National Formulary, American Pharmaceutical Association, which are part of the necessary equip-

ment of every drugstore in the country, describe the color of the drugs and chemicals. The names used in these descriptions have accumulated from many sources at various times, and with no official standard names the editors were appalled with the jumbled inexactitude of the resulting descriptions. An appeal first made to the Bureau of Standards led to the formation of the Inter-Society Color Council.

FORMATION OF THE INTER-SOCIETY COLOR COUNCIL

The Inter-Society Color Council grew out of a color conference and exhibit sponsored by the Revision Committee of the U. S. Pharmacopoeia at Washington, May 14, 1930, Professor E. N. Gathercoal in charge. Several proposals were considered for furthering this work, such as the formation of a new color society, referring the whole matter to the Colorimetry Committee of the Optical Society of America, or asking the National Bureau of Standards to do the work. The initial form in which the Council was set up resulted from a proposal of the late Mr. Irwin G. Priest, at that time the leading figure in the progress of color. This proposal in the form of a resolution which had been discussed and adopted by the Executive Committee of the Optical Society of America read:[21]

> It is the sense of the Executive Council of the Optical Society of America that the need for better organization of those interested in the description and specification of color which found expression at the "Color Conference" held in Washington, May 14, 1930, can best be met by the formation of a joint council consisting of officially designated representatives of the several national societies and associations interested in the description and specification of color.

The Inter-Society Color Council was formed essentially as proposed by Mr. Priest. Its articles of organization and procedure can be briefly paraphrased. The aims are to stimulate and coördinate the work of the various member societies so far as they relate to color. There are at present two types of memberships, (*a*) member bodies, (*b*) individual members.

(*a*) Member bodies must be societies of national scope, operating on a non-profit basis. The ultimate authority for policies and affairs of the council is vested in the member bodies. Member bodies pay $25 yearly dues and are entitled to appoint at least three but not more than ten accredited delegates who represent that member body in all the activities of the council. (The Society of Motion Picture

Engineers has at present three delegates and is thus entitled to appoint seven more.)

Three of these delegates shall be designated by the member body which they represent as voting delegates, one of which shall be designated by the member body as the chairman of the delegation. The duty of this chairman is to report to the member body all proceedings of the Council of interest to the member body and to transmit to the proper officials of the member body any reports of the council that he thinks should appear in the publications of the member body. It is also one of the duties of the accredited delegates in general and the chairman of each delegation in particular to bring to the Inter-Society Color Council any problems of particular interest of his member body in the field of color.

(*b*) Individual members, dues $5 per year, have all privileges of accredited delegates except that they may not hold office. The individual delegates as a group may elect three of their members who become accredited delegates with the privilege of voting and holding office. All members and voting delegates receive copies of the *News Letter*, minutes of the meetings, and reprints of technical papers presented at joint sessions of the council held with member bodies. The total income of the council amounts to about $600 per year.

The Council at present is made up of 74 delegates appointed by 11 member societies, and by 67 individual members. It functions as a joint committee on color of the member societies favored with the advice of the individual members.

Each delegation functions much as does any technical committee of a society. It is supposed (*1*) to secure papers of interest to the Society, to be presented at conventions and published; (*2*) to secure agreement on technical matters involving many individuals or harmonize diverse interests, particularly when such interests are represented also in other societies; (*3*) to standardize; (*4*) to collect authoritative information; or (*5*) to encourage research.

All these functions can often be more effectively performed when meeting with delegates and experts representing other organizations but interested in the same common object. Reading the list of member bodies should make the possibilities evident. These are:

American Association of Textile Chemists and Colorists
American Ceramic Society
American Psychological Association
American Society for Testing Materials

Illuminating Engineering Society
National Formulary, American Pharmaceutical Association
Optical Society of America
Technical Association of the Pulp and Paper Industry
The Textile Color Card Association of the United States
U. S. Pharmacopoeial Convention
The Society of Motion Picture Engineers

In developing the color names recommended to the U. S. Pharmacopoeial Revision Committee,[22] the Council obtained for one of its member bodies the advice of the color experts of two other member bodies (the Optical Society of America and the American Psychological Association); it obtained for this member body the coöperation of the National Bureau of Standards, which had previously been sought and refused; and the Council served as an authoritative source of information not swayed by commercial considerations for deciding which of the various competing systems of material color standards was best suited to derivation of the color names. In all this work the allied interests of another member body (the Textile Color Card Association) were protected by the presence of its delegates at the Council meetings.

It may not be amiss at the present time to mention specifically the work of another of the member bodies. In the clothing, house furnishing, and other industries catering to the retail trade, many fancy color names are used with the idea of attracting the attention of the style-conscious public. As examples of such fancy names the following may be quoted from recent advertisements occurring in the New York newspapers:

Sleeping Blue	Dusty Rose	Trichlor
Daring Pink	Daring Red	Maize
Matisse Blue	Solar Yellow	Heaven Pink
	Blossom Blue	

To the scientific-minded such names are hardly informative, but to the cool-headed business men who are responsible for furnishing these colors in many types of clothing, and who wish to combine other articles of apparel from hats, blouses, sweaters, skirts, stockings, shoes, rubbers, purses, buttons, to curtains, tapestry furniture covers, and any other things that must either be alike or must harmonize, such names should be as fully standardized as anything else, or the manufacturers of dyestuffs, the weavers, the dyers, the manufacturers of rubber, leather, and miscellaneous fixings would be in such utter

confusion that economic manufacture of the gaily colored and rapidly changing styles would be utterly impossible and the smooth assembling of harmonious color combinations would be in the state of utter confusion of a century ago.

In order to remedy this situation the Textile Color Card Association of the United States, Inc., was established in 1915 for the purpose of standardizing commercial colors for the benefit of industry to give accurate information to the manufacturers of such articles.

Upon inquiry of Mrs. Rorke, Secretary of the Textile Color Card Association, it was found that the above fancy color names are to the manufacturers not as vague as they would appear to the public. Each is the result of carefully prepared samples which have been distributed to the manufacturers and can at present be represented fairly accurately in the Munsell system. It is expected that the next revision of the Standard Color Card of America, which is the 9th edition, containing about two hundred colors, will not only bear the fancy names but they will be defined in exact spectrophotometric measurements and expressed in terms of the chromaticity diagram of the ICI 1931 Standard Observer and coördinate system, and also in terms of the Munsell Book of Color, the Maertz & Paul Dictionary of Color, and the ISCC—NBS (Inter-Society Color Council—National Bureau of Standards), standard color names.

As previously mentioned, the particular irritation that started the formation of the Inter-Society Color Council was the search for a good set of color names. This was not difficult, but it was a much more laborious task to ascertain which colors best fitted these names; that is, what colors most people would associate with these names. This work is best described[23] in Research Paper *RP1239* of the Bureau of Standards, "Method of Designating Colors," by Deane B. Judd and Kenneth L. Kelly. As usual with government Bureaus, the results are as impersonal as possible but it was practically a necessity to express the results in terms of the sample "chips" in the Munsell Book of Color. Not only were these color chips used but also special colored papers, carefully measured on the spectrophotometer, were made available for the investigation by the Munsell Color Company. The problem was presented to the Color Council in the following words:

A means of designating colors in the U. S. Pharmacopoeia, in the National Formulary, and in general pharmaceutical literature is desired; such designation is to be sufficiently standardized as to be acceptable to science, sufficiently broad

to be appreciated by art and industry, and sufficiently commonplace to be understood, at least in a general way, by the whole public.

Briefly described, the hues of all colors will be designated by five well known color names, red, orange, yellow, green, and blue, typical of the spectrum and four others, purple, pink, brown, and olive. At first it was attempted to designate certain browns as dark orange, as indeed they are, but later it seemed more advantageous to keep the more usual names. Similarly, pink and olive are so well known as to make other names seem artificial. The result is that some hues have two or three names, depending upon whether a light or dark representative is described. This description can best be illustrated in Table I. The use of abbreviations is encouraged. When a hue is about halfway between two main hues, both names are used and both initials are capitalized. When one hue is used only as a modifier to indicate the direction in which the color is altered, the suffix *ish* or a lower-case initial is used.

TABLE I

Table of Hue Designations

Red or pink	R or Pk
Reddish orange, or orange pink, or reddish brown	r O O-Pk r Br
Orange or brown	O, Br
Yellowish orange or yellowish brown	Y O, Y Br
Yellow or olive brown	Y Ol-Br
Greenish yellow or olive	gY Ol
Yellow green or olive green	YG Ol-G
Yellowish green	yG
Green	G
Bluish green	b G
Greenish blue	g B
Blue	B
Purplish blue	p B
Bluish purple	b P
Purple	P
Reddish purple	r P
Red purple or purplish pink	R P or p Pk
Purplish red or pink	p R or Pk

The relative reflecting power or lightness of the colors is designated by the five terms *very dark*, *dark*, *medium*, *light*, *very light*, making five rough gradations in this respect.

The saturation or vividness of the colors have six designated degrees, but the names differ in accordance with the lightness of the

color approximately in accordance with the following design: (*1*) neutral: white, gray, or black; (*2*) nearly neutral, but inclined toward one of the named hues: use the suffix *ish*, as *reddish, pinkish, brownish, yellowish, olive, greenish, bluish, purplish* (Table II).

TABLE II

White	-ish white	Very pale	Very light		
Light gray	Light-ish gray	Pale	Light	Brilliant	Vivid
Medium gray	Medium-ish gray	Weak	Moderate	Strong	Vivid
Dark gray	Dark-ish gray	Dusky	Dark	Deep	Vivid
Black	-ish black	Very dusky	Very dark	Very deep	

With this system of names in mind it was necessary to designate the exact color to which each name should apply, and to set the limits between which each name should be used. This work was done mostly with colored samples supplied by the late Walter T. Spry of the Munsell Color Company. Part of these were the regular series used in the Munsell Book of Color and part of them were special. All the significant special samples have been measured for their colors.

A second proposal of the Committee on Color Problems[24] is a code in which to express approximately the spectral transmission of color-filters or the spectral reflectance of colored objects.

Certain standard wavelengths are used for the measurements. The transmission for each wavelength is expressed in numbers from 0 to 9, assigning certain values for each numeral. The entire spectral curve is expressed in a number of seven digits, as 5100999 for a rose pink, or 8710004 for a medium blue.

The wavelengths used and the transmissions to be expressed by each numeral are as given in Table III.

TABLE III

Digit	Wavelength Millimicrons	Digit	
1st	440	0	less than 0.01
2nd	480	1	0.01 to 0.04
3rd	520	2	0.04 to 0.08
4th	560	3	0.08 to 0.15
5th	600	4	0.15 to 0.25
6th	640	5	0.25 to 0.35
7th	680	6	0.35 to 0.45
		7	0.45 to 0.60
		8	0.60 to 0.75
		9	more than 0.75

In addition to the two major projects just described, the Council has prepared a survey of the standard color terms used by the different member bodies. The first draft is a 42-page mimeograph pamphlet.

A list of persons outstanding in scientific, technical, educational, and industrial fields of color, but not including all users thereof, has been collected and printed under the title of *Who's Who in Color*, which can be obtained through the secretary of the Council.* Available also are large coördinate sheets of the ICI mixture diagram, and the symposium on color tolerance; copies of the 1938 symposium on the Hardy recording spectrophotometer included in the October 1938 Journal of the Optical Society of America; of the 1940 symposium on spectrophotometry in the Paper Industry; and other symposiums on the subject of color will be obtainable as they become available.

The Inter-Society Color Council is what its name implies, a joint committee formed from several societies. Its *News Letters* issued to its members in mimeograph form to describe the progress of color work, notices of important color publications, the activities of its planned meetings, is not intended as a competing journal, but, with the minutes of the meetings, serves as a basis for reports by the delegates to the member societies which can be printed in their own publications.

The Council sponsors meetings with the member societies on the subject of color. The resulting papers have appeared in the journals of the respective societies, and in reprints distributed to the delegates and members. Such joint meetings have been held with the Optical Society of America, The Technical Association of the Pulp and Paper Industry, and The American Psychological Association. A joint technical session has been scheduled during the convention of the Illuminating Engineering Society, September 9th–12th at Spring Lake, N. J., and another during the 1941 spring meeting of the American Society for Testing Materials, to be held at Washington, D. C., in March, 1941. It is hoped that a similar joint meeting may be arranged some time in the future with the Society of Motion Picture Engineers.

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DISCUSSION

DR. GOLDSMITH: Why are not simple numerical values suggested for the designation of colors? Would it not be simpler to use numerical coefficients for color designation rather than such vague terms as turquoise, lilac, or pink, for example? If a standard color-temperatur were selected for the illumination, and the trichromatic components of a color determined on a standard equipment having fully disclosed characteristics, the color designation would be definite. Should there not also be provided a relatively simple piece of apparatus capable of duplicating such designated colors speedily for the use of those who have an interest in definite color values? And is it not further a fact that in the long run verbal designations will hardly prove as adequate as numerical designations?

DR. GAGE: That was carefully studied, but we would get a designation in x and y which was very accurate. The Railway and Aviation specifications say the y of a certain red glass, for example, shall not exceed 0.295. It is all right for specification purposes, but the ordinary individual would not understand it.

DR. GOLDSMITH: The type of color-producing equipment which seems to be needed would be one having, for example, three adjusting dials on it which might be set to the trichromatic coefficient values of a particular color. That color might then appear on a screen or sheet of ground-glass or similar surface. If such a device were capable of practical production at this stage of the art it would appear to be the most convenient and readily usable solution to the color-matching problem.

DR. GAGE: I am going to answer that quite frankly and tell you what the people working on that kind of thing have actually found. An elaborate apparatus was assembled at the National Bureau of Standards[25] in which a single wavelength of the spectrum could be mixed with white light and compared directly with the color being studied, after which the per cent white and spectral color was measured. This method has not been continued as it did not prove to be as satisfactory as finding the position of a color on the chart from its spectrophotometric measurements. These curves can now be easily made with the Hardy spectrophotometer and analyzed in such a way that we get the x and y coördinates of the color and its reflection factor. That is the accurate way of doing it. It is not the way that we can honestly recommend for ordinary color work with the hope of being understood by the average individual. The interpretation of results expressed in the x and y coördinates can be done in this way: The standard color papers in the Munsell Book of Color have all been studied by Glenn and Killian, working at the Massachusetts Institute of Technology under Professor Hardy. Standard samples have been measured on the spectrophotometer. We know their x and y coördinates. Therefore, when we take a copy of this Munsell Book of Color, we can refer to that and say that a given sample has such x and y coördinates. Or, if we say that here is a color which has certain x and y coördinates, what does it look like? We can refer to the table and find out which of the samples in the chart will have those x and y coördinates. Much the same analysis is being done with the Maertz & Paul Dictionary of Color that

was gotten out for another purpose. That shows the color names for all these colors which have appeared through the ages—turquoise blue and Nile green, and so on.

DR. GOLDSMITH: In Maertz & Paul's Dictionary of Color there are about a thousand definitely named colors and perhaps four times as many unnamed colors. It takes a considerable amount of time to locate any specific color. It is by no means certain that, in color matching, the effect of the illumination to which the color samples are subjected for examination or comparison does not influence too greatly the matching results. It is also uncertain whether the degree of matte structure of the color sheets in the "dictionary" and in the color sample may not be sufficiently different to invalidate the matching results at certain angles of illumination. Can such color-matching methods serve as more than a first approximation, as compared to the precision of trichromatic-coefficient determination or spectrophotometric measurements?

DR. GAGE: It is a first approximation and I would suspect that about 400 years from now the Munsell papers would not have exactly the same color and would not have the same position on the triangle that they have now. It would be possible, at that time, to measure them on a spectrophotometer, and find out where they were on the triangle and tell how much they have drifted, to mix up some more colors and get back to the exact colors we have now.

DR. GOLDSMITH: Do you believe that the printed sheets of colors are reasonably permanent?

DR. GAGE: They are the best that can be had in material standards. They have not drifted enough so that anybody can tell yet that they have drifted. Of course, it is not known exactly what they were ten years ago.

MR. CRABTREE: One of our immediate interests is the specification of paints and drapes used in the studios for color photography. How do you designate them at the present time?

MR. HOBART: In the color-control department the charts are used for the general purpose of letting the people in the studio see what range of colors is available. Colors for costumes or sets are chosen chiefly from past experience. The producer is shown a sample of the color and the result on the screen after the color is photographed in Technicolor.

MR. KELLOGG: There is a special consideration in judging colors of liquids as would be required for druggists. It would seem that samples of opaque colors on a chart would be very different. When judging the color of a liquid, it is usually held up to a light, and one shade is seen when looking through a considerable thickness and another shade when looking through only a little of the liquid. Would a wedge on a card or a wedge of stained glass be any better for comparing, or as a visual standard, than a simple solid block?

DR. GAGE: The method which was worked out and which was reported in the Bureau of Standards research paper on the subject, is to put the liquid in a standard cell, and hold it up so as to look through the liquid at a white paper illuminated with the same light as the Munsell pages. When you find the chip which comes nearest the color of the liquid in the cell under those conditions, that is the name that you give it.

Of course, great precision is not required in this. There are only about 150 color names in this system. The New York *Times* published a statement that

there were something like 2,000,000 different colors; actually, a good eye can perceive something like 10,000,000 colors. If precision is required, a spectrophotometric curve is made.

A piece of yellow paper might actually have no yellow in it whatever; only red and green, with the yellow taken out. Or it might have yellow and nothing but yellow. But one may wish to know which type of yellow it is, which might be of importance in photography. Two colors may look alike to the eye but would photograph differently.

All those things can be determined by careful analysis; but if only a general idea of whether a liquid is a saturated color, for example, or a weak color, or whether it is, in general, red, green, or blue, light or dark, the system of color names is adequate.

MR. MARTIN: I spent a number of years in an experimental theater where we used the Munsell Color System for keeping a record of the colors used in settings and properties, and found it valuable when it was necessary to reproduce them at future presentations of the same show. This application of the Munsell Color System is still being used at the same theater, more as a record of what has been done than in planning original sets.

MR. CRABTREE: Did you run into any snags, or was it adequate?

MR. MARTIN: We found it adequate in describing the colors. The difficulty was in matching them the second or third time. But we usually came close.

MR. RICHARDSON: In the beginning color on the screen was very poor, because only a few of the finer shades could be reproduced. Have any tests been made to show how far we have advanced in the rendition of color on the theater screen?

DR. GAGE: Some work on that was done by MacAdam, Yule,[9,10,11] and others, and was reported in the *Journal of the Optical Society of America*. They made a very thorough analysis of how much distortion is likely to occur in the subtractive process, and of methods of correcting it by special additional printings. A given process is likely to produce distortion in a certain way. Instead of projecting distorted colors on the screen, or colors we do not want, why not distort the colors in front of the camera, so that when they appear on the screen they will be correct?

All such things are receiving most excellent study.

THE THEATER STANDARDIZATION ACTIVITIES
OF THE
RESEARCH COUNCIL OF THE ACADEMY OF MOTION PICTURE ARTS AND SCIENCES*

JOHN K. HILLIARD**

The Research Council of the Academy of Motion Picture Arts and Sciences, handling coöperative technical problems for the industry, is, by its very nature, interested in many of the problems confronting theater owners.

The Research Council was organized in 1934 by the major Hollywood studios for the fundamental purpose of getting pictures of better quality upon the screen at a lower net cost through higher net efficiency.

After its organization, the Research Council devoted most of its time to problems concerned primarily with motion picture production—especially the coördination of sound recording within the various studios.

Preliminary Work.—When investigating that subject, we found that the sound reproduction in different theaters varied to such an extent that it was impossible to obtain uniform quality under existing conditions. It was very evident that a coördinating program was vitally necessary. As a result the Research Council Theater Standardization Committee was appointed late in 1936.

As a first step in this program, the Committee conducted hundreds of listening tests in many different theaters, in order that each member of the Committee would have a wide experience with field conditions and so that all members of the Committee would have a common understanding upon which to base this program.

Each member of the Committee is a technical expert in the field of sound and all the past experience of the Committee, coupled with

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* Presented to the Pacific Coast Conference of Independent Theater Owners at Los Angeles, May 9, 1940.

** *Chairman,* Research Council, Theater Sound Standardization Committee.

this group experience, has given us a wide knowledge and understanding of the subject which has proved to be of tremendous benefit to us in our Committee work.

Early in this program we assembled a test-reel containing a short length of a regular release print from each of the studios. This assembled reel, with both picture and sound, was used as a means of coördinating listening tests held in the theaters.

This particular test-reel proved to be so valuable to us here in Hollywood, that prints were made available at cost, upon request, to service companies, equipment manufacturers, and theaters. Since its original release we have revised and shortened the reel and the several hundred prints now in use throughout the world have been of great help in adjusting theater equipment.

All the major theater service and manufacturing companies are now using the Research Council Theater Sound Test Reel to adjust theater equipment on a uniform quality basis.

As you will realize, our ultimate aim is to make sound from all studios reproduce equally well in each theater—at least to bring all theaters up to a commercially acceptable quality-level.

The Research Council naturally recognizes the value of engineering, testing, and checking of theater equipment, but we have based our entire theater standardization program upon the fundamental fact that the final determination should be a *listening* test, and I mean a listening test of the *equipment* as *installed* and *adjusted* in the theater. For this reason all our standards have been based so far upon listening tests correlated with engineering data.

From an engineering standpoint, the ultimate aim in this work is the specification of acoustical standards which will place these listening tests upon a scientific basis. At the present time there is not sufficient acoustical information available upon which to base any standard acoustical specifications. The Research Council has a Committee working on this problem, which we hope will eventually assemble enough data to permit setting up standard methods of acoustical measurements that will be of use in adjusting theater equipment.

STANDARD METHODS FOR THEATER ADJUSTMENT

As a result of the Committee's experience and listening tests with our theater reel, a standard method of theater adjustment for all the better known sound systems has been set up and, wherever possible,

equipment manufacturers and service organizations are following these specifications when installing and maintaining equipment.

Experience has shown that the use of these standard adjustments leads to the best overall quality obtainable with current sound recordings as reproduced on theater equipment with two-way horn systems. In most cases a slightly different adjustment is necessary for each make and type of loud speaker system. However, hundreds of recent installations have borne out the fact that if theaters are so adjusted, the product of any one producer is not penalized, and the overall quality of all product is more uniform.

The quality obtained is modified, of course, by acoustical conditions in the theater itself, but it has also been found that even where bad acoustical conditions exist the effect of these conditions on the product is minimized if these standard adjustments are used.

The usual manner in which this type of standardization takes place is through the manufacturing and service organizations, as they are in closer touch with the studios and with technical advancements which may take place at the source of the product. Accordingly, the exhibitor is not always conscious of the fact that this sort of progress is taking place. Consequently we are striving to make our activities of actual, tangible benefit to the exhibitor.

PERFORMANCE STANDARDS FOR THEATER SOUND EQUIPMENT

One thing which we have done along this line is to prepare recommendations on performance standards for theater sound-reproducing equipment. Prior to the issuance of these recommendations, you as exhibitors were forced to rely primarily upon statements of salesmen for information as to equipment which you might be considering for purchase.

After conferences extending over a year's time, participated in by representatives of the studio sound departments, equipment manufacturers, and the theater servicing groups, the Research Council published these recommendations, and you as exhibitors now have an unbiased, impartial source of information on the standards up to which any sound equipment should measure.

While we do not, of course, advise on specific equipments by name, we have set up minimum requirements for equipment performance which are sufficient to guide you in these matters. One thing you may be sure of—if you follow our recommendations, you will avoid buying equipment which is not representative of the best available.

On the other hand, such equipment will have no unnecessary features which would add to the cost of installation and maintenance.

Our standardization activities have been considered so important by the sound equipment manufacturers that during the past few years all the major equipment manufacturers have sent representatives to Hollywood to consult with us every few months. In addition, permanent Hollywood representatives are maintained here by a number of companies who coöperate with the Committee and with whom we are in constant consultation.

Thus, you can be assured that the Hollywood studios and the sound equipment manufacturers are going along step by step, and this coöperation between these two groups of the industry will insure your getting the maximum benefit from every dollar spent by you on equipment replacement or maintenance.

The Committee has spent many hours in conference with representatives of these manufacturers, discussing the design of individual equipments so that new equipments brought out from time to time will give the best possible quality with current studio recordings.

As a result of this phase of our program it is now possible for the exhibitor to purchase better sound equipment at a lower price than would have been possible without the Committee's coördinating efforts. While the Committee can not, of course, claim credit entirely, we believe, for example, that we have contributed to making it possible for you now to purchase 50 watts of power in your equipment for the approximate price of $2^1/_2$ watts ten years ago.

POWER REQUIREMENTS FOR THEATERS

Let me briefly discuss the matter of power. Many people believe that the volume of sound—that is, the loudness—that can be obtained in a theater depends entirely upon the amount of power installed. This is only partially true. Power is required for increased loudness for the proper presentation of special effects such as the earthquake in *San Francisco*, the breaking up of the icebergs in *Spawn of the North* or the breaking of the dam and the resulting flood in *The Rains Came*. But also from a quality standpoint adequate power is necessary to reproduce dialog and music at normal levels without harshness and unnaturalness.

As a result of a great deal of study of amplifier power requirements, the Academy Research Council is issuing recommendations on the minimum power requirements for theater sound systems. These

recommendations indicate the minimum power which should be installed in any theater in order to give proper reproduction of current sound recording. Fig. 1 indicates these minimum power requirements.

You will note that the following power for specific seating capacities is required:

Number of Seats	*Minimum Power Requirements*
0– 400	10 watts
400– 600	13
601– 750	15
751–1000	20
1001–1250	26
1251–1500	32
1501–1750	37
1751–2000	43
2001–2250	48
2251–2500	53
2501–2750	59
2751–3000	65
3001–3250	70
3251–3500	76
3501–3750	82
3751–4000	88
4001–4250	93
4251–4500	98
4501–4750	104
4751–5000	110
5001–5250	115
5251–5500	121
5501–5750	126
5751–6000	132

It can be easily recognized that the minimum power of 10 watts is entirely within reason. The average modern radio in your home has 5 watts, and the better sets have 10 to 15 watts of power. You may rest assured that this amount of power would not be available unless it was necessary from a quality standpoint—especially in this day of inexpensive radios where price competition is so important.

We hope that the exhibitors will take advantage of our work and will consult our recommendations when you purchase any equipment so you will receive at least the power recommended for whatever size theater you are equipping.

All of Hollywood's sound is being recorded with these power requirements as a basis, and if these recommendations are followed you will be assured of obtaining the best possible quality from all types of recording.

Adequate power as recommended by the Research Council is of definite commercial value to you, as it gives you sound quality comparable to the best available and increases customer enjoyment.

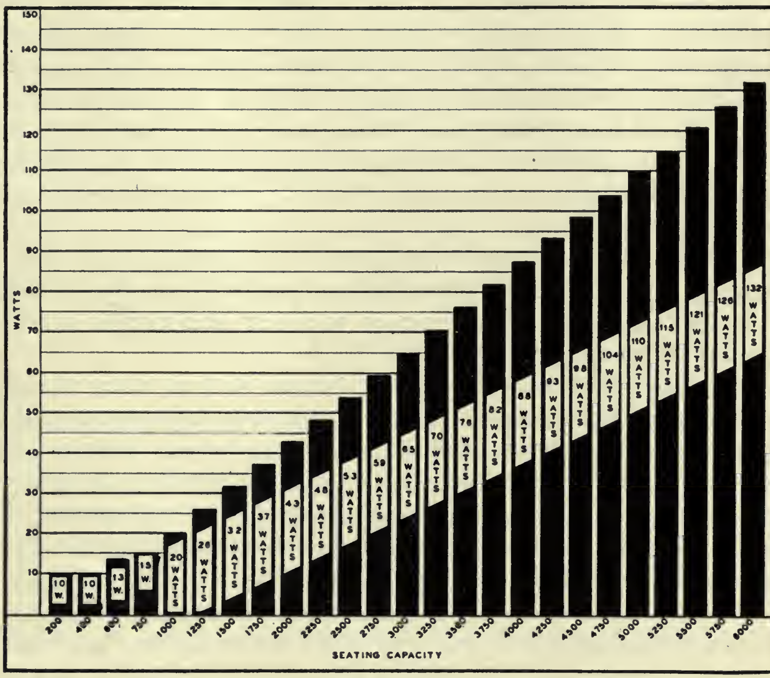

FIG. 1. Academy Research Council minimum power requirements for theaters (minimum recommended amplifier output based upon seating capacity of the auditorium).

THEATER ACOUSTICS AND SOUND LOUDNESS IN THE AUDITORIUM

I might point out one fact which has become very apparent to us since the start of our work—that many theaters encounter difficulties with their sound because of acoustic deficiencies. Our experience indicates that many exhibitors do not realize the necessity of attempting to remedy these acoustic deficiencies rather than to try to get around them by means of electrical adjustment of the sound equipment.

Often only a few dollars worth of material properly placed in the auditorium or backstage will improve results tremendously—by giving greater sound uniformity throughout the theater so that the maximum number of seats, regardless of their position in the auditorium, can be utilized with no discomfort to the audience.

Theater owners often spend considerable money and give lots of thought to the subject of comfort. You work diligently to achieve eye comfort by putting a good picture on the screen. You spend money for good seats and carpets. You maintain clean and well equipped rest rooms, and attractive lobbies. But one type of comfort which in our experience we have found to be neglected is ear comfort. If your patrons must strain to hear the sound, or if they are subject to raucous and overlouded sound, they will become tired just as rapidly from ear fatigue as from eye fatigue or bodily discomfort.

To achieve ear comfort, it may not be necessary to spend lots of money. Poor sound conditions can be corrected very often at small cost, the main effort being proper technical information and the manner of applying it.

Difficulty encountered in setting volume level in many theaters also results from acoustic deficiencies, in particular because of non-uniform distribution of sound throughout the house. This problem is decreased or entirely eliminated with proper distribution throughout the auditorium as given by recommended two-way speaker systems, which are universally considered to give the best results of any speakers now available.

We have received complaints from time to time from the field stating that some release prints will not run throughout the show on one fader setting. We realize that all of you are concerned with this problem. In the majority of cases this trouble can be traced either to poor acoustical conditions or to improper sound equipment adjustments. Where an auditorium is highly reverberant in particular frequency bands—for instance, where deep male voices are accentuated, the sound level in such sequences in the reel will appear too loud for other portions of the picture. This will necessitate a fader change in such a house, while in a theater with proper acoustics the same feature will play throughout on one fader step.

Thus it may be seen that proper acoustics contribute tremendously to the ease and time, such as projectionist and servicemen's time, required to obtain the best sound quality and the proper volume, and

tend to maintain the proper sound level at a single fader setting throughout the feature.

Here again the commercial aspect should be given consideration as poor acoustics lead to complaints at the box-office because of poor quality and improper sound level.

VOLTAGE REGULATION

A common difficulty leading to fader changes within a single feature is poor regulation of the power supply to the theater, *i. e.*, the incoming a-c line voltage from the power company's supply line varies from time to time. In many instances the change in line voltage is sufficient to vary the acoustic power in the auditorium as much as 400 per cent. It is advisable in all installations where perfect line voltage regulation is not available to install a voltage regulator as part of the sound equipment. This voltage regulator will maintain a constant voltage to the equipment and thus a constant power level in the theater regardless of wide line voltage variations.

INCREASING UNIFORMITY OF PRODUCT

In the early days of sound, each producer made his product to conform to his own individual standards, thus necessitating constant adjustment by the serviceman as the theater ran the product of different studios. At the present time you will find a much greater degree of uniformity of product than four or five years ago, and we are all continually striving to remove any differences still existing and to eliminate the necessity for any adjustment of theater equipment to fit individual product.

The Academy Research Council is performing a real service to exhibitors at the present time by furnishing information to you, by setting standards for performance for theater equipment, and in helping to coördinate recording in the studios with reproduction in the theaters. Everyone connected with the organization is extremely proud of what has been accomplished since the start of this work.

RESEARCH COUNCIL SERVICES TO EXHIBITORS

We will be able to be of even greater service to you in the future by placing the facilities of the Research Council at your individual service to advise you on your equipment problems. Any exhibitor considering the purchase of new equipment will be interested in knowing that all our Bulletins on theater standardization, including the one con-

taining our recommendations on performance standards for theater equipment, are available to you and we will be glad to furnish copies upon request.

If you are interested in receiving copies of these Bulletins, write to the Research Council office and we will be glad to send this material to you and place your name on our mailing list so that copies of future material of interest to exhibitors will come to you as issued.* We want you to know that the Research Council and its Theater Standardization Committee are interested in your problems, and that we welcome your inquiries and your requests for information, and we stand ready at all times to coöperate in any way possible to assist you to get better quality in your theater.

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* Requests for this information should be addressed to the Academy Research Council, 1217 Taft Building, Hollywood, Calif.

IMPROVEMENTS IN MOTION PICTURE LABORATORY APPARATUS*

C. E. IVES AND E. W. JENSEN**

Summary.—*A machine for cleaning motion picture film by dry wiping has been equipped with a reservoir and distributing system so as to fit it for application of a cleaning liquid. In order to prevent dust from being carried into the roll when film is rewound, the wind up is enclosed in a box into which filtered air is pumped at a sufficient rate to maintain a forceful discharge stream at the point where the film enters. This stream dislodges dust particles.*

In order to have sufficient light on a meter in a darkroom the face of the meter is covered with a metal hood containing a suitable safelight. The meter is observed through a small aperture which permits very little light to escape into the room. Self-luminous finder buttons used as markers in a darkroom can be protected from dirt and corrosion by mounting them in an inverted glass ignition tube which is sealed at the open end with a thermoplastic.

A developing machine roller is provided with frictional driving engagement with the shaft on which it is mounted by the use of spring-held shoes which bear against the shaft.

Oscillation in a mechanical filter in the drive train of a continuous printer has been subdued by the use of Koroseal strips in place of springs and friction damping.

The present article is the third in a series[1,2] in which some twenty-five items related to motion picture laboratory equipment and practices have been discussed. The subjects treated in this paper are as follows:

(*1*) Cleaning equipment for negatives
(*2*) A dust-free windup
(*3*) The illumination of meters in a darkroom
(*4*) A method of mounting self-luminous buttons
(*5*) A friction drive roller.
(*6*) A mechanical filter for printer driving

(1) CLEANING EQUIPMENT FOR NEGATIVES

It is found necessary to clean motion picture negatives before making the first print and then periodically during the making of

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** Eastman Kodak Co., Rochester, N. Y.

release prints to remove dust, oil specks, and other loose or adherent material which, although present in such small quantity as not to be very noticeable on visual inspection, is quite offensive in a projected print. This is frequently done by passing the film between the surfaces of a folded piece of silk plush wetted with carbon tetrachloride or other oil solvent. The plush pad is held in the hand while the film is drawn through its folds slowly enough to permit evaporation of the liquid so that it is not carried into the winding roll.

FIG. 1. Modified Neumade cleaning machine (front).

Hand operation of the rewind has the advantage of requiring constant attention and permitting stops when necessary to give additional care where required. This procedure has the usual shortcomings of discontinuous hand work where a well controlled uniform treatment is required throughout a considerable length of film. The rate of application of the cleaning solvent varies above and below the optimum and stops must be made several times when cleaning a 1000-ft roll to apply more cleaning liquid. If atmospheric conditions are not favorable, moisture sometimes condenses on the surface of the pad when it is opened out for the addition of cleaning solvent and is

transferred to the film, causing spots. The plush is not utilized effectively since it is necessary to fold back the edges to avoid dropping lint on the surface of the film.

The use of a machine capable of applying the cleaning liquid at a uniform rate under proper conditions of frictioning is therefore in the interest of both quality and economy. For the reasons already stated the operation should include inspection. Therefore, the mechanical aid need only carry out the cleaning proper while the film is propelled

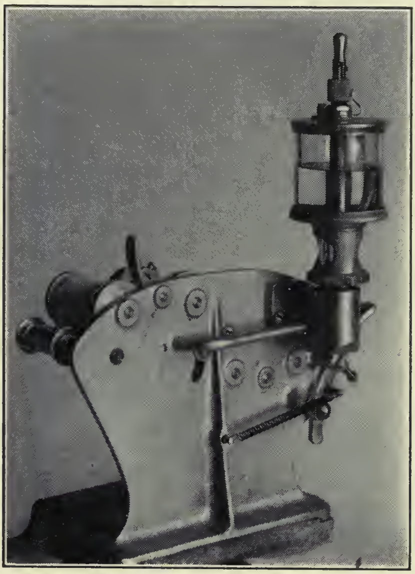

FIG. 2. Modified Neumade cleaning machine (back).

by a hand-driven rewind or a motor-driven unit, the speed of which is controlled by a treadle switch, as was described in an earlier paper.[2]

Modifications to a Commercially Available Machine.—Cleaning machines are available on the market which, with some modification, can be made to carry on this function. Figs. 1 and 2 show the front and back, respectively, of the Neumade cleaner as modified for this purpose. It consists of a vertical main frame of cast-iron which supports at the front two tables covered with plush ribbon, against which the support and emulsion surfaces are rubbed in sequence as the film passes in a horizontal direction through the machine. In

addition, guide rolls at the point of entry and exit of the film, as well as spools for feeding the silk plush ribbons across the tables, are supported by this same frame. As sold, no provision exists for the continuous supply of cleaning liquid, so that either dry brushing or the intermittent application of the liquid can be employed. Experience has shown that while under certain conditions the dry brushing is useful, the use of a solvent liquid is necessary to cope with either oily or adherent material.

The principal modification required, therefore, was the addition of a reservoir and distribution system capable of supplying enough liquid for cleaning the largest size of roll. This was accomplished by installing a device commonly used to supply oil to machinery, which has glass walls, so that it is possible to see at all times the quantity of liquid in reserve and the rate at which it is delivered by the adjustable needle valve.

Below this feeder a plenum chamber was made from which tubes were led to the vicinity of the wiping tables through the main frame. A piece of wicking stuffed in the ends of these tubes has the twofold function of limiting the rate of flow and carrying the liquid across the gap between the end of the fixed distributing tubes and the adjustable tables. The wicks are led into small tubular cells fastened to the underside of the tables where they feed the liquid to strips of felt which extend through slots cut in the tables. Capillarity is used to carry the liquid upward another one-half inch and to distribute it across the $1^3/_8$-inch width of the wiping ribbon. Adjustment of the wicks is easily made and seldom requires changing. As a result of the control exerted by the wicks, an equal flow of liquid to the two tables can be maintained without any particular attention being paid to levelling.

The main frame and all rollers were chromium plated with undercoatings of copper and nickel. It was found best to make the tables of stainless steel or canvas-reinforced Bakelite.

Extensive use of the modified cleaning machine has shown that it can be used without danger to the film and with good economy of cleaning solvent.

(2) A DUST-FREE WINDUP

Even if the cleaning operation is entirely effective, dust particles are likely to be deposited on the surface of the film between the cleaning machine and the windup. The accumulation of an electro-

static charge, a likely occurrence if the humidity is low, aggravates the condition by attracting dust. Air must be supplied to the vicinity of the film as the solvent fumes are swept away into an exhaust duct but the cleaning pads must not be in the path of a stream of moist air lest moisture be condensed on them.

The consequence of these requirements is that the film after leaving the cleaning machine usually passes through the air of the room which can not be regarded as dust-free even when great care is taken to keep it clean. In order to prevent winding dust particles into the film roll they must, therefore, be dislodged just ahead of the windup.

FIG. 3. Dust-free windup.

This dust-free winding condition was attained by enclosing a standard rewind in a metal box (Fig. 3) which was supplied with filtered air. The box was provided with a well fitting door to permit threading and removal of the roll and a window for observation. Most of the air supplied to the box was forced to escape at the opening where the film entered. Thus, a clean atmosphere was provided at the point of winding while the force of the escaping air swept the dust from the entering film. The beneficial effect was readily found in improved cleanliness of prints.

The air supply in the unit illustrated was obtained by supplying compressed air to a compartment at one end of the box from which it escaped through filtering flannel into the rewind chamber. This arrangement was principally a matter of convenience and permitted carrying the unit to a number of other locations where it was used for

determination of the possibility of eliminating dirt at the source. It was found that much loose dirt picked up in such operations as splicing could be dislodged, readily eliminating the possibility of abrasive action in subsequent rewinding.

If, for any reason, it became necessary to apply more force to remove firmly adherent particles, pneumatic squeegee nozzles could be added to the dust-free windup as shown in the drawing of Fig. 4.

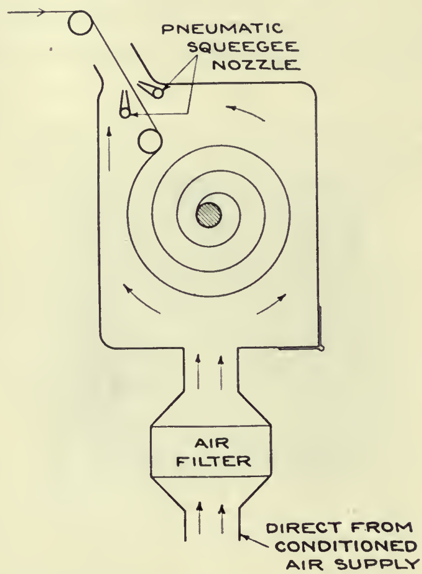

Fig. 4. Dust-free windup with pneumatic squeegee.

(3) DARKROOM LIGHTING

The extension of color sensitivity and the continuing advance in speed of motion picture negative films have reached the point where the general illumination of darkrooms is of little use. By far the greatest part of the resulting difficulty has to be met by the arrangement of work and equipment and the design of highly automatic machinery for film handling and for controlling conditions. Certain aids are available where no good substitute for visual observation is practicable. Two of these are described as follows:

Meter Illumination.—It is frequently desired to use meters of standard design, such as ammeters, in darkrooms where fast panchromatic

materials are handled. If the meter must be observed continually from a location near the sensitive material, the intensity of illumination which is safe to use is wholly inadequate for accurate observation of the meter, particularly with the parallax type which has a mirror and a knife-edge pointer. Even when a safelight is installed near the face of the meter, the illumination is still insufficient.

Under some circumstances, it is possible to employ a visually acceptable level of illumination if the time of exposure is limited by the use of a normally open switch operated by a push-button so that the light is on only momentarily. It is preferable, in the interest of both convenience and exposure safety, to maintain an acceptable illumination on the meter dial continuously, without allowing more than a small portion to reach the surroundings.

A completely safe method would consist of enclosing the meter in a hood having a mask, which fits closely to the user's face, in combination with a suitable automatic switch for cutting off the illumination when the aperture in the mask is not closed. Where the equipment must be used by more than one person, difficulties in design are encountered in addition to the objection which exists on the basis of sanitation.

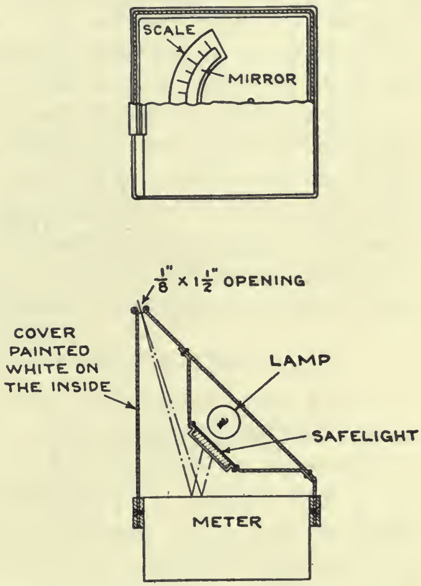

FIG. 5. Illuminated meter.

By following this general principle, but making a slight concession in the matter of stray light, a practical design has been realized. This is illustrated in Fig. 5. Essentially, it consists of a box with a slit in the top which is just large enough for convenient viewing but allows only a very small proportion of the light to escape from within. In the case illustrated, the meter forms the bottom of the box. The top is tapered to permit close access without contact with the face. The upper edges are rounded for safety.

In the present case, readings had to be made throughout a distance of slightly over 1 inch along the scale. A slit $^1/_8$ inch in width by $1^1/_2$ inches in length was adequate.

When a greater extent of scale must be used, observation can be accomplished through an arcuate slit extending along the whole scale or through a hole opposite the pointer axis which, of course, places the eye in line with the pointer, whatever the position of the latter.

With an instrument having a broad pointer, lighting should be diffuse to eliminate any well defined pointer shadow. When the instrument is of the parallax type, the safelight or some bright area on the inside of the housing must be visible in the mirror at the position of the dial where the reading is made.

When the view of a meter is restricted, as it is by the use of such a small viewing aperture, some additional care must be given to the matter of convenience of the viewing angle, *etc.* Thus, the hood illustrated, while of peculiar shape, fits the demands of the situation where it is used. Hooded meters, when viewed almost vertically downward, accommodate differences in stature somewhat better than when the direction of view is horizontal.

(4) A METHOD OF MOUNTING SELF-LUMINOUS BUTTONS

The "Radieye Locator" or self-luminous button, available on a screw mounting for use on electric wall switches, is very convenient in darkrooms for marking the location of indicator devices, control levers, door frames, the projecting edges of machines or movable equipment, *etc.* In a period of 2 minutes, visual dark-adaptation after leaving a light room is usually sufficient to permit seeing the buttons, while much longer time is needed when dependence is placed on a safelight. The total light spread throughout a room by the use of a reasonable number of the locators is almost negligible, although the placement should be such as to prevent the illumination of sensitive film at short range.

In some locations the most visible area is a horizontal surface. When on a horizontal surface in a developing room, and particularly if in a protective recess, the locators are subject to chemical attack and are very short-lived.

Fig. 6 shows a method of mounting luminous buttons designed to provide adequate protection against breakage of the button, to prevent corrosion, and to require little, if any, cleaning. The luminous button is screwed into a cork stopper which, in turn, is fitted tightly

into a thick glass ignition tube cut down in length, the luminous button facing the bottom of the tube. The open end of the tube is sealed with oxygenated asphalt or some other corrosion-resisting plastic.

To protect the sealed tube against breakage, it is mounted in a board placed at the desired guide point. Drain holes in the board prevent the accumulation of liquids around the sealed tube.

Luminous buttons mounted as described have been used successfully in a developing room where the exposure to corrosives was severe.

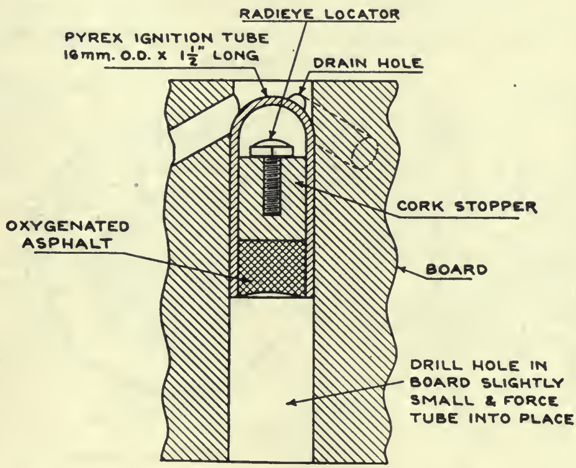

FIG. 6. A mounting for self-luminous buttons.

(5) A FRICTION DRIVE ROLLER

A friction drive roller for use in developing machinery, mentioned in a previous publication,[3] has been found adaptable and, in fact, is readily adjustable for use under varied conditions. In long film-driving trains, as in developing machines, problems arise which require the introduction of some degree of additional drive or of braking action which can be furnished by such a roller.

The obtaining of varying degrees of coupling between a roller and the shaft on which it is mounted is made convenient by the use of the design shown in Fig. 7. The outside roller dimensions are identical with those of the non-driving rollers. The roller is also supported on the shaft in the usual way and, in fact, can be converted to an idle roller in an instant.

Driving engagement with the shaft is obtained through a pair of pressure pads which are held in contact with opposite sides of the shaft by the pressure applied by an arcuate stainless steel spring. These pads are separate from the roller but lie within apertures in the roller hub. When a force is applied to bring about rotation of the roller relative to the shaft, the friction pads are made to slide over the shaft surface. The resistance to sliding depends, of course, on the spring pressure which can be adjusted by shaping the spring as required. The rollers do not bear on the pads radially so that the braking force is not disturbed by the action of the roller.

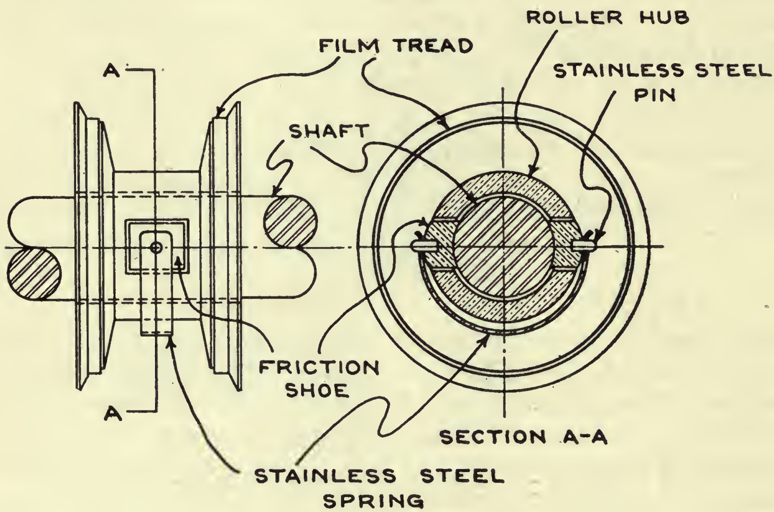

FIG. 7. A friction drive roller.

The spring is held from slipping off by fitting it over a stainless steel pin in the outer surface of the pad. The surface of the pad is slightly crowned. No part of the driving force is applied to the spring so that its pressure on the pads remains constant.

(6) A MECHANICAL FILTER FOR PRINTER DRIVING

The design of a filter drive consisting of a flywheel and flexible coupling for improving the uniformity of running speed of a continuous motion picture printer was described in a previous paper.[2] Numerous mechanical filter designs are, of course, in use in various types of sound-recording and sound-reproducing equipment and have

been described in the JOURNAL. The design described in the reference cited involved the use of a section of rubber hose for the flexible coupling. Damping at the coupling to suppress oscillation at the natural frequency of the filter system was provided only by the properties of the hose material.

Somewhat later, when better suppression of low-frequency oscillation was required, the hose coupling was replaced by a spider carrying four pairs of opposed extension coil springs which were packed tightly with cotton wadding to provide the required damping. This arrangement (Fig. 8) suggested by Dr. O. Sandvik of these Laboratories, proved satisfactory under the regular operating conditions with the shaft running at 90 feet per minute and was used for some

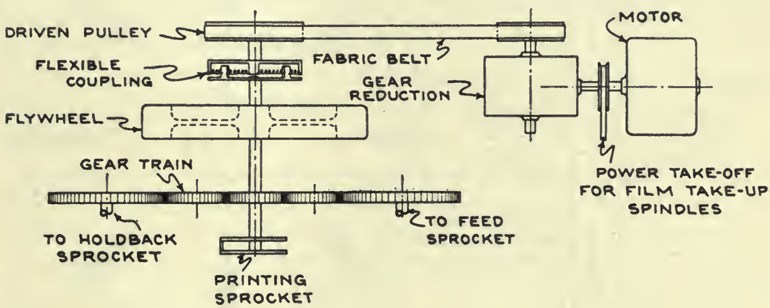

FIG. 8. Filter drive on continuous printer.

time performing the multiple function of flexible (alignment) coupling, resilient filter member, and damping device.

Recently it was desired to operate this machine at the much slower speed of 23 rpm and at the same time have, if possible, increased uniformity of exposure. The necessary speed reduction was obtained by a change in the ratio of pulley diameters carrying the woven belting which connected the precision reduction gear and the filter. The larger pulley mounted next to the filter was made of cast aluminum and was cut away to reduce the rotatory moment. The resulting natural frequency for the pulley-spring combination was thereby maintained much higher than that of the flywheel-spring combination so that oscillation was not aggravated too much by coupling of these systems.

Studies of the motion of the printer sprocket were made by the use of a Strobotac and by making flash exposures through a much nar-

rowed aperture and developing the printed film to a gamma of 4.0. A densitometric study of the print showed the comparative absence of high-frequency disturbances but the presence with both the 23 and 90 rpm drives of a degree of oscillation at the natural frequency of the flywheel-spring system (about 4 cps) which was about equal in each case but objectionable for the intended low speed use. A disturbance of the same frequency and amplitude is more serious in its photographic effect at the lower speed than at the higher because the *fractional* modulation in exposure is greater.

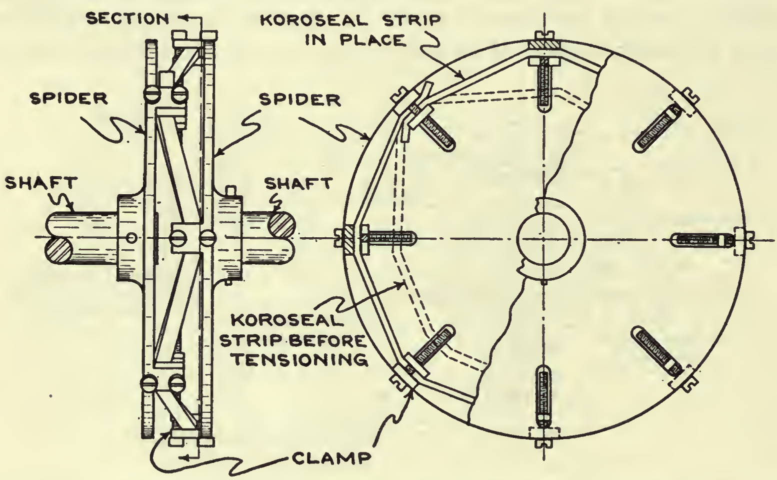

FIG. 9. Modified flexible coupling.

Since it was desired to effect the required improvement in damping by the least extensive change in the equipment, an effort was made to improve the frictional damping as applied directly to the springs. Springs of the same type were set up separately from the printer and loaded with weights so as to obtain the normal deflection. A number of different ways of applying friction to the bodies of the spring were tried but it was soon found that whenever sufficient damping was introduced to suppress the oscillation in the desired degree a great increase in stiffness occurred.

A solution was sought, therefore, in the substitution of some material for the springs which would have more suitable properties. Such a material was found in the synthetic rubber-like material, plasticized vinyl chloride polymer, sold under the name of "Koroseal, Grade

116."[4] This substance has the feel and appearance somewhat like those of soft rubber but different mechanical characteristics. When it is released after stretching under tension it does not snap back instantly but returns at a rate which diminishes as the original dimensions are approached.

This material purchased in sheet form $^1/_{16}$ inch thick was mounted on the spiders of the coupling as shown in Fig. 9. The spiders were provided with screw clamps as shown. Two 12-inch strips of the Koroseal, each $^1/_{16}$ inch by $^3/_{16}$ inch in section, were threaded together through the open clamps, alternately passing from one spider to the other. The ends of the strips were secured in the clamp at the starting point. Then the remaining clamps were taken up, all of them being moved sequentially in a series of small steps so as to extend all portions of the strip uniformly until each clamp gripped the material firmly. The 12-inch length between the end fastenings effects about a 23-per cent stretch in the length of the strip when the radial distance of the seven remaining movable jaws is changed about 28 per cent.

As expected from the preliminary tests the oscillation was greatly reduced so that uniformity of running speed and, consequently, of exposure time was improved in the required degree. The spider is not equipped with stops so that the Koroseal spring member has to transmit starting and stopping acceleration. The Koroseal spring is now used for both 23- and 90-foot-per-minute printers and, after two years, is judged to be sufficiently rugged for permanent use.

REFERENCES

[1] CRABTREE, J. I., AND IVES, C. E.: "Improvements in Motion Picture Laboratory Apparatus," *Trans. Soc. Mot. Pict. Eng.* (May, 1924), No. 18, p. 161.

[2] IVES, C. E., MILLER, A. J., AND CRABTREE, J. I.: "Improvements in Motion Picture Laboratory Apparatus," *J. Soc. Mot. Pict. Eng.*, **XVII** (July, 1931), p. 26.

[3] IVES, C. E.: "An Improved Roller Type Developing Rack with Stationary Drive," *J. Soc. Mot. Pict. Eng.*, **XXXI** (Oct., 1938), p. 393.

[4] SCHOENFELD, F. K., BROWNE, A. W., JR., AND BROUS, S. L.: "Recent Developments with Koroseal," *Ind. & Eng. Chem.*, **31** (Aug., 1939), p. 964.

BROUS, S. L., AND SEMON, W. L.: "Koroseal—A New Plastic," *Ind. & Eng. Chem.*, **27** (June, 1935), p. 667.

DISCUSSION

MR. WILLIFORD: I think I might add a little to your description of the polymerized polyvinyl chloride, known as Koroseal, by saying that in general appearance it looks like rubber and stretches like rubber; but it is unlike rubber

in that instead of coming back immediately its recovery is slower. Whether that is beneficial in your damping or not I do not know. When you stretch Koroseal you wonder whether you have stretched it past its elastic limit; but it comes back. It is a unique material, and I am interested in the application you have made of it.

MR. IVES: That effect can not be simulated by any combination of springs or anything else that I know of. The property is easily demonstrated. The rate of return or restoration of the original dimensions in point of time is apparently limited. This material (No. *116*), recommended by the manufacturer, for the purpose, after we first worked the thing through with another type is a black material. Until you start pulling it, as Mr. Williford said, you might think it was a piece of soft rubber. The material is available in different degrees of stiffness. It has other peculiarities in its tensile properties.

MR. KELLOGG: One of the nicest kinds of mechanical filters, if absolute synchronism between two machines is not required, is to run a belt around two large rollers between which is a pair of idlers just as you have shown. If the idlers are permitted to move back and forth, they will introduce the required flexibility for filtering, and it is especially easy in this arrangement to attach a suitable damping element. It makes a convenient and cheap type of filter which might be applicable to your case if you wanted to use it.

MR. IVES: I suppose some of the magnetic devices described in Mr. Kellogg's paper might be used for this type of problem.

MR. CRABTREE: I want to urge other members to prepare similar papers along these lines. All of you must have a lot of ideas stored away, none of which in themselves you might think big enough to justify a paper; but if each of you contributed only one idea a year that would be a valuable contribution to knowledge. In fact, I had in mind establishing a section of the JOURNAL for "stunts and gadgets." Perhaps we would not use precisely that title, but it would enable the engineer to publish a lot of information which at the present time, is being lost because he is too modest to publish it, or thinks it is not big enough to justify a technical paper.

TECHNICAL NOTES

Readers are invited to submit for publication in this section of the Journal brief items of technical information pertaining to the industry.

A SYSTEM FOR REDUCTION OF 120-CYCLE MODULATION FROM A-C OPERATED EXCITER LAMPS*

J. R. COONEY**

The following is a method, applicable particularly to low-priced sound equipment and portable apparatus, for allowing the use of a-c operated exciter lamps with practical elimination of 120-cycle modulation effects on the reproduced sound.

The system depends upon the fact that the current in a gas-filled phototube is a function both of the light incident upon the cathode and the potential applied to the anode—the latter effect being due to increase in ionization of the gas atoms as the voltage is increased. It therefore becomes possible to compensate for periodic

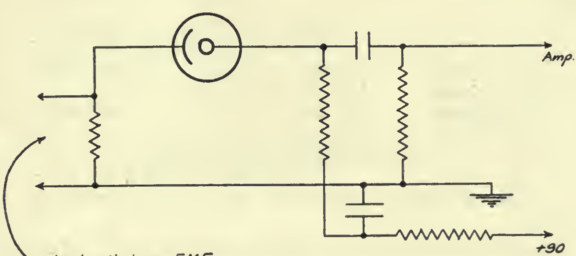

FIG. 1. Compensation for light variations by introduced a-c emf.

variations in the exciting light by inserting, in series with the PEC anode potential, an alternating emf having the proper phase, amplitude, and wave-form. (Fig. 1). Furthermore, as the effect of this a-c introduction on the PEC space-current depends entirely upon the number of primary electrons emitted from the cathode by illumination, the adjustment holds very closely for all degrees of average illumination (as determined by a sound-track, *etc.*, interposed between exciting light and phototube) down to zero.

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* Received July 25, 1940.

** Waldo Theater Corp., Waldoboro, Me.

In other words, it is necessary to make only one adjustment of the balancing voltage—say, with no film in the sound head—corresponding to the percentage variation in illumination of the particular type of exciter lamp being used, and the cancellation remains substantially constant for all degrees of illumination as determined by the sound-track.

There are various ways in which a suitable neutralizing voltage may be obtained. The unfiltered or partially filtered sections of the amplifier power-supply

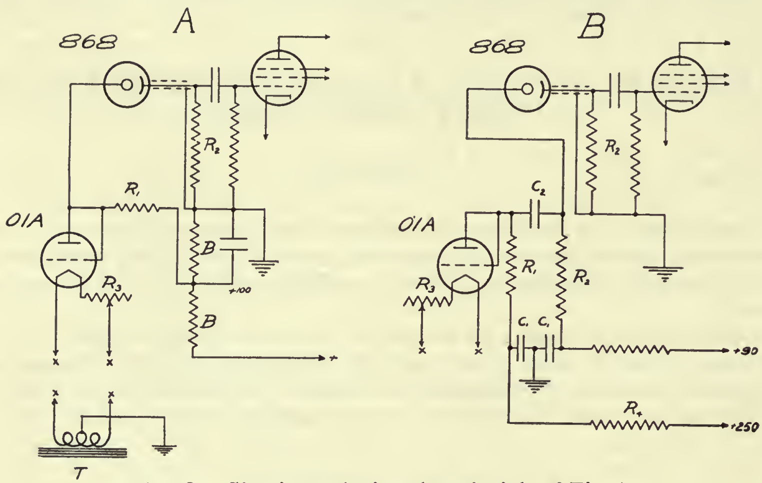

FIG. 2. Circuit employing the principle of Fig. 1.

R_1	5,000 ohms	1/2 watt	C_1	1 or more	mfd
R_2	500,000 ohms	1/2 watt	C_2	0.1	mfd
R_3	20 ohms	rheostat	B	Bleeder	
R_4	50,000 ohms	1 watt			

T 6.3-volt amplifier heater supply
E_f (*01A*) $\simeq$ 3v. rms: $I_p \cong 2$ ma.
Exciter lamps 10-v, 7.5a; 10-v, 5a; 9-v, 4a; *etc.*

contain a 120-cycle component that may be adapted, by suitable networks, for the purpose.

Fig. 2 illustrates a simple circuit giving excellent results experimentally. Here a 120-cycle voltage of nearly perfect wave-form for the purpose is obtained by utilizing the space-current variations in a filament-type tube operated below temperature saturation.

A shows a simple, direct-coupled circuit, which however has the disadvantage that a fair-sized bleeder is required to insure substantial independence of the d-c PEC potential from variations in the 01*A* circuit. This disadvantage is removed in *B*, in which the d-c circuits are isolated. In both cases adjustment is made by regulating the 01*A* filament current (as the tube operates saturated it is unnecessary that the filament be balanced with respect to ground).

This arrangement, in either case, gives a cancellation of the order of 30 db, when used with any of the commonly used types of exciter lamp, but has the disadvantage of being rather sensitive to power-line variations.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

American Cinematographer

21 (September, 1940), No. 9

Berndt's 16-Mm Sound Film Recorder Revolutionary (pp. 389–390, 430) — W. Stull

Twentieth Century Fox Holds Preview for Its Big Camera (pp. 396–398) — W. Stull

Constructing and Using 16-Mm Blimp for Kodachrome Sound (pp. 410–412) — H. Hunt

British Journal of Photography

87 (July 26, 1940), No. 4186

Progress in Colour (pp. 363–364)

87 (August 9, 1940), No. 4188

Progress in Colour (pp. 387–388)

87 (August 16, 1940), No. 4189

Progress in Colour (pp. 398–399)

Electronics and Television and Short-Wave World

13 (August, 1940), No. 150

Frequency Characteristics of Film-Recorded Sound (pp. 356–357), Pt. II — R. H. Cricks

Institute of Radio Engineers, Proceedings

28 (July, 1940), No. 7

Acoustics in Studios (pp. 296–299) — M. Rettinger

International Photographer

12 (September, 1940), No. 8

High-Speed Camera (pp. 8–9)

Twentieth Century Camera (pp. 17–18) — D. B. Clark

Guarding Negative Quality (p. 22) — S. C. O'Brien

International Projectionist

15 (July, 1940,) No. 7

New Lenses for Projecting Motion Pictures (pp. 7–8, 11, 28–30) — W. B. Rayton

Theater Sound System Optical Data (pp. 12, 15–16) — R. J. Kowalski

Sound Track Standards Revised (pp. 17, 28), R.C.A. Sound Service Tools (pp. 21–22), Pt. II

15 (August, 1940), No. 8

Sound Screens: Structure and Function (pp. 7–8) — G. F. HOLLY

Technical Data Anent Metal Film (pp. 10, 12) — R. W. CARTER

Audience Noise *vs.* Volume Range (pp. 14–15, 23–26) — W. A. MUELLER

Commercialization of Non-Reflecting Surfaces (p. 16)

The Projectionist's Interest in Auditorium Viewing Conditions (pp. 19–20) — B. SCHLANGER

Motion Picture Herald (Better Theaters Section)

140 (August 24, 1940), No. 8

Fitting Reproduction into the Studio-Theater Sound System (pp. 35–36) — A. NADELL

What Today's Sound System Must Do (pp. 37–39) — W. W. SIMONS

1940 FALL CONVENTION

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Headquarters

Headquarters of the Convention will be the Hollywood Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Daily hotel rates to SMPE delegates will be as follows (European Plan):

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	8.00–14.00
Parlor suite and bath, 2 persons	12.00–16.00

Room reservation cards, mailed to the membership early in September, should be returned to the Hotel immediately to be assured of satisfactory accommodations.

Indoor and outdoor garage facilities adjacent to the Hotel will be available to those who motor to the Convention.

Members and guests of the Society will be expected to register immediately upon arriving at the Hotel. Convention badges and identification cards will be supplied which will be required for admittance to the various sessions, studios, and several Hollywood motion picture theaters.

Railroad Fares

The following table lists the railroad fares and Pullman charges:

City	*Railroad Fare (round trip)*	*Pullman (one way)*
Washington	$132.20	$22.35
Chicago	90.30	16.55
Boston	135.00	23.65
Detroit	106.75	19.20
New York	135.00	22.85
Rochester	124.05	20.50
Cleveland	111.00	19.20
Philadelphia	135.00	22.35
Pittsburgh	117.40	19.70

The railroad fares given above are for round trips. Arrangements may be made with the railroads to take different routes going and coming, if so desired,

but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

Technical Sessions

The Hollywood meeting always offers our membership an opportunity to become better acquainted with the studio technicians and production problems. Technical sessions will be held in the *Blossom Room* of the Hotel. Several evening meetings will be arranged to permit attendance and participation by those whose work will not permit them to be free at other times. The Local Papers Committee is collaborating closely with the General Papers Commitee in arranging the details of the program.

Studio Visits

The Local Arrangements Committee is planning visits to several studios during the Convention week. Details will be announced in the Programs. Admittance to the studios will be by registration card or Convention badge only.

New Equipment Exhibit

An exhibit of newly developed motion picture equipment will be held in the *Bombay and Singapore Rooms* of the Hotel, on the mezzanine. Those who wish to enter their equipment in this exhibit should communicate as early as possible with the General Office of the Society at the Hotel Pennsylvania, New York, N. Y.

Semi-Annual Banquet and Dance

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, October 23rd, in the *Blossom Room.* A feature of the evening will be the annual presentations of the SMPE Progress Medal and SMPE Journal Award. Officers-elect for 1941 will be announced and introduced, and brief addresses will be delivered by prominent members of the motion picture industry. The evening will conclude with entertainment and dancing.

The Informal Get-Together Luncheon will be held in the *Florentine Room* of the Hotel on Monday, October 21st, at 12:30 P. M.

Motion Pictures

At the time of registering, passes will be issued to the delegates to the Convention, admitting them to the following motion picture theaters in Hollywood, by courtesy of the companies named: Grauman's *Chinese* and *Egyptian* Theaters (Fox West Coast Theaters Corp.), Warner's *Hollywood* Theater (Warner Brothers Theaters, Inc.), Pantages *Hollywood* Theater (Rodney Pantages, Inc.). These passes will be valid for the duration of the Convention.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. L. L. Ryder, *hostess,* and the Ladies' Committee. A suite

will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; Beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the SMPE motion picture exhibit); Mexican village and street, Los Angeles.

In addition, numerous interesting side trips may be made to various points throughout the West, both by railroad and bus. Among the bus trips available are those to Santa Barbara, Death Valley, Agua Caliente, Laguna, Pasadena, and Palm Springs, and special tours may be made throughout the Hollywood area, visiting the motion picture and radio studios.

Those who wish to visit San Francisco may arrange for stop-over privileges when purchasing their railroad tickets. Arrangements have been made with the Hotel Mark Hopkins for single accommodations for $5 daily and double with twin beds for $7, both with baths. The Fairmont Hotel also extends a rate of $4 single and $6 double, with bath. Reservation may be made by writing directly to the Hotel.

W. C. KUNZMANN,
Convention Vice-President

ABSTRACTS OF PAPERS OF THE FALL CONVENTION AT HOLLYWOOD, CALIF.

OCTOBER 21-25, 1940

The Papers Committee submits for the consideration of the membership the following abstracts of papers to be presented at the Fall Convention. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate discussion. The papers presented at Conventions constitute the bulk of the material published in the Journal. The abstracts may therefore be used as convenient reference until the papers are published.

J. I. Crabtree, *Editorial Vice-President*
S. Harris, *Chairman, Papers Committee*
C. R. Sawyer, *Chairman, West Coast Papers Committee*

L. A. Aicholtz	F. M. Falge	F. H. Richardson
P. Arnold	R. E. Farnham	W. H. Robinson
C. N. Batsel	C. Faulkner	C. R. Sawyer
L. N. Busch	C. Flannagan	J. Stewart
O. O. Ceccarini	L. D. Grignon	H. G. Tasker
G. A. Chambers	E. W. Kellogg	R. Townsend
A. C. Cook	G. E. Matthews	P. R. von Schrott
L. J. J. Didiee	R. F. Mitchell	I. D. Wratten
A. C. Downes	W. A. Mueller	C. K. Wilson
	W. H. Offenhauser	

Black Light for Theater Auditoriums; H. J. Chanon, *General Electric Co.*, Cleveland, Ohio, and F. M. Falge, *General Electric Co.*, Los Angeles, Calif.

The demand for near-ultraviolet radiation, commonly called "black light," in the production of fluorescent effects has shown the need for a technical approach to the problem. New technics of measurement as well as design information, data on sources and material are necessary to insure most effective use of these new media.

The paper covers design information on the lighting of fluorescent carpet, decorative wall and ceiling murals, and other decorative applications. Information on light-sources, standard filters for absorbing the visible light emitted by the sources, as well as response characteristics of various types of fluorescent materials have been obtained. The effect of extraneous visible light in masking the brightness of the fluorescent material is discussed. One convenient method of measuring the near-ultraviolet energy from mercury light-sources in existing installations is explained.

Acoustic Design Features of Studio Stages, Monitor Rooms, and Review Rooms; D. P. Loye, *Electrical Research Products, Inc.*, Hollywood, Calif.

A survey was made of studio experience, as one step in the determination of the most nearly ideal design characteristics practicable for studio stages, review rooms, and other units. Acoustic measurements were also made of Hollywood studio units of these types. These data were correlated with the information obtained in the survey, and used as a valuable guide in the determination of the optimum characteristics and dimensions recommended for major studio scoring stages, monitor rooms, dubbing rooms, review rooms, and studio theaters.

These data are described in detail, and recommendations regarding the studio units are given. These recommendations include the optimum reverberation and other acoustic characteristics, and also the most practicable sizes which experience and theoretical considerations indicate to be desirable.

Information regarding Hollywood preview theaters is included in an appendix.

Stability in Synchronous Motors; S. Read, Jr., and E. W. Kellogg, *RCA Mfg. Co., Inc.*, Camden, N. J.

For the most part, since the advent of talking pictures, motors have been employed whose performance is above reproach. The various types of motor, however, differ widely in their ability to resist load irregularities and in their tendency to oscillate when a disturbance occurs. For the more critical applications these factors deserve careful consideration when the type or design is being selected. The principal types of synchronous motor are (*1*) the variable-reluctance or induced-pole motor, (*2*) the separately excited motor, (*3*) the ac-dc motor, (*4*) the hysteresis motor, (*5*) the low-speed multi-tooth motor (of the type used for electric clocks), (*6*) the polyphase, uniform torque modification of number *5*, and (*7*) selsyn motors.

Many of the characteristics of synchronous motors may be best understood by assuming that the polyphase winding produces a uniformly rotating magnetic field, but estimating the stiffness and stability demands a knowledge of the manner in which the a-c input varies with mechanical displacement. Generous pole-face grids are essential for stability. Ac-dc motors have certain elements of instability as well as stabilizing factors, which are not present in straight synchronous motors. The magnitude of these effects can to some extent be controlled by the external circuit arrangements. Selsyn motors are less readily damped than regular synchronous motors, and for this reason arrangements by which the synchronous motors can be interlocked from standstill are of interest.

Ground-Noise Reduction Systems; E. W. Kellogg, *RCA Manufacturing Co.*, Camden, N. J.

The principal purpose of the paper is to formulate a statement of the desired characteristics of a ground-noise-reduction system, in terms of such factors as prompt opening, peak reading, and filtering. In this it is assumed that anticipation is not employed. It is desirable to limit the filtering to a single stage of resistance-capacity filtering (or equivalent). Slow closing helps filtering and peak reading. The better the peak reading properties of the circuit, and the less the filtering delay, the smaller can the margins be made without causing too frequent clipping.

A number of circuits are discussed which have been proposed for improving the filtering without sacrifice of quick opening, or reasonably rapid closing.

In some operations, anticipation is entirely practical, and if this is done it appears possible to provide an almost perfect envelope current.

Editing a Motion Picture; I. J. Wilkinson and W. Hamilton, *RKO Radio Pictures, Inc.*, Los Angeles, Calif.

The paper is an attempt to reduce to words a portion of the mechanical and artistic elements involved in the process of editing a motion picture. The authors realize that they are dealing with a highly controversial subject but feel that, as there is so little pertinent material available on this phase of motion picture production, this paper may serve as a preliminary to a study on a larger scale.

Consideration is given to the origin of film editing and its advancement from the purely mechanical craft of the early days to its present status as a contributing factor in the entertainment and dramatic values of the motion picture of today.

Demonstration film is presented to illustrate various editing technics and to show the possibility of their use as a means of drastically altering original story and dramatic conception.

Line Microphones; H. F. Olson, *RCA Manufacturing Co.*, Camden, N. J.

A line microphone is a microphone consisting of a large number of small tubes with the open ends, as pick-up points, equally spaced along a line and the other ends connected by means of a common junction to a transducer element for converting the sound vibrations which converge upon the junction into the corresponding electrical variations. Several types of line microphones with the useful directivity along the line axis are described as follows: a simple line, a line with progressive delay, and two lines with progressive delay and a pressure gradient element.

A Line Type of Microphone for Speech Pick-up; L. J. Anderson, *RCA Manufacturing Co.*, Camden, N. J.

The development of a line type of microphone is discussed, having directional characteristics which are relatively independent of frequency, and which are of such size as to be readily portable. Uniform directional characteristics are obtained by constructing the line in such a way that the effective length becomes less with increasing frequency. Physical size limitations are largely responsible for confining the microphone to speech pick-up applications.

A Method of Calibrating Microphones; F. L. Hopper, *Electrical Research Products, Inc.*, Hollywood, Calif., and F. F. Romanow, *Bell Telephone Laboratories*, New York, N. Y.

Methods of determining the performance characteristics of microphones by acoustic measurements are described. Factors involving the accuracy of the methods are discussed. The correlation between a microphone's performance as determined by acoustic measurement and by listening tests is reported. Application of both types of test to a studio type of cardioid microphone is given as an example.

General and Design Considerations of Low-Noise Microphones; A. L. Williams and H. G. Baerwald, *The Brush Development Co.*, Cleveland, Ohio.

With the development of the microphone art toward increased fidelity, thermal agitation noise becomes the principal limitation and therefore a major problem. Its physical side has been discussed in a recent publication where the factors on which noise performance depends have been analyzed, and a suitable noise rating based on aural perception has been proposed. The purpose of this paper is to outline some practical consequences. Different microphone types are discussed in regard to their noise performance and, particularly, to their inherent limitations of noise reduction. Multiple piezoelectric microphones which lend themselves particularly well to the design of quiet units, are treated in more detail. The noise performance of different sound-cell types is given including a recent developmental unit which tends to realize the inherent efficiency of the piezoelectric type of microphone to a fuller extent. The practical realization of the qualities of piezoelectric units in a microphone depends on a suitable choice of the associated circuits and tubes; the principles and limitations of their design are indicated. Application is also made to the design of minimum-noise combinations of different microphone types, particularly to an adjustable-hypercardioid (unidirectional) combination of ribbon and sound-cell type. Some performance data of a corresponding experimental model are given.

A 200-Mil Variable-Area Modulator; R. W. Benfer and G. T. Lorance, *Electrical Research Products, Inc.*, Hollywood, Calif.

A modulator using a new vibrating-mirror unit has been developed for recording double-width variable-area sound-track. The noise-reduction shutter is at the slit, making it possible to record, with noise reduction, Class *A* push-pull track comprising two standard bilateral tracks, one of which is located in accordance with the dimensional standards for single track. While this has been its principal use to date, it is readily adaptable for other types of track. A visual monitor shows operation of the noise-reduction shutter and the amplitude of signal modulation in both directions from the base-line with a positive indication of peak overload. An exposure meter is included to serve as a check on lamp current and track balance. The light-source is a tungsten filament lamp which will properly expose fine-grain emulsions to "white" light or standard emulsions through an ultraviolet filter.

An Investigation of Some Factors Influencing Volume Range in Photographic Sound Recording; W. K. Grimwood and O. Sandvik, *Eastman Kodak Co.*, Rochester, N. Y.

This is an extension of an earlier investigation of background noise. The present paper deals more specifically with the relation between volume range and the type of photographic materials and the sensitometric conditions used. A brief study of the effect of the spectral quality of the radiation used in recording and printing is included.

Measurement of Photographic Printing Density; J. G. Frayne, *Electrical Research Products, Inc.*, Hollywood, Calif.

When the spectral sensitivity of positive film is simulated by the use of a suitable combination of phototube and optical filter in the integrating sphere densitometer, the printing density of any type of negative, irrespective of grain size, with

any type of base or backing, may be accurately determined. Printing density is practically independent of the type of light-source or filtering employed in the printer. Relationships between printing and visual diffuse densities for various types of negatives have been established.

Stabilized Disk Record Cutters; S. J. Begun, *The Brush Development Co.*, Cleveland, Ohio.

Where it is desirable to obtain good quality in disk recording, the cutter used must have a wide frequency range and a low content of harmonic distortion. Furthermore, care must be exercised that the sensitivity of such a cutting device should not be affected by temperature changes. This is particularly important in case the recording equipment, for some reason, does not work in air-conditioned rooms.

The sensitivity, as well as the amount of harmonic distortion generated for magnetic and crystal cutters, depends upon the temperature. In a magnetic cutter, the characteristic of the damping material varies sufficiently with temperature change to require constant temperature conditions. With respect to a crystal cutter, it has been found that a crystal element will drive a recording stylus with negligible distortion if its temperature is of the order of 30°C or above. For this reason, a crystal cutter has been developed with a built-in thermostat to control a heating element, which will keep the cutter temperature constant within narrow limits.

The design of such a cutter and the performance characteristic are described in detail. The high degree of stability of such a temperature-controlled cutter is shown.

A Portable Disk Recording-Reproducing Machine; J. C. Davidson and C. C. Davis, *Electrical Research Products, Inc.*, Hollywood, Calif.

The *RA-280* equipment is intended as a portable high-quality disk recording and reproducing machine. It was designed primarily to include a feed-back recorder, a vertical and lateral reproducer, and an amplifier with equalizers and suitable switching arrangement for recording or reproducing.

The turntable drive includes an electrically and mechanically balanced motor, a precision worm and gear, and an oil damped mechanical filter. Vibration is prevented from reaching the turntable by a bellows type coupling. The filter consists of a reed-type spring surrounded in oil and provided with suitable linkage to the turntable.

It is felt the electrical and mechanical requirements for a high-quality machine have been met. The frequency flutter has been maintained at ±0.03 to ±0.06 per cent and mechanical-noise pick-up is below the threshold of feeling and shows no optical pattern in the recording.

An Improved Playback Horn Equipment; G. R. Daily, *Paramount Pictures, Inc.*, Hollywood, Calif.

A dolly-mounted, high-quality two-way horn system for playback and announcing service on production recording stages is described. A reflex-type horn cabinet is mounted on a four-wheel steerable dolly, together with a 50-watt amplifier and cable reel. The horn unit can be rotated on the dolly to direct it at the ac-

tion, or be readily removed from the dolly for use on parallels, or suspended from ceiling girders. An extension connection is provided for a W.E. *750-A* speaker for low-level direct recording of playbacks. An extension director cut-out horn control is provided. The mixers' playback control box provides, (*a*) mixing from any two of four film or disk input positions; (*b*) extensions for cueing by phone monitored by the director or actors; (*c*) connections for portable disk recording from a bridging circuit across the film recording main amplifier output, and (*d*) film recording connection from the playback circuit.

Improved Motor Drive for Self-Phasing of Process Projection Equipment; H. G. Tasker, *Paramount Pictures, Inc.*, Hollywood, Calif.

Process projection photography requires that the shutter of the projector and that of the camera open and close simultaneously. The relation between the shutter speeds and the pole frequencies of normal motion picture motor systems is such that there may be one, four, or five incorrect shutter relationships for each correct one, if the motors are interlocked at random. Earlier methods of insuring correct phasing between camera and projector shutters did not take proper account of the economic importance of fast and reliable operation. This paper presents the results of a time and economic study indicating savings of many thousands of dollars annually per studio, accruing from the use of a motor system which automatically phases the shutters of camera and projector, and which has a very high degree of reliability. The design and performance features of such a motor system are described in their relation to earlier efforts along this same line, together with a report on three months' production use on the new system.

Twentieth Century Camera; G. Laube, *Twentieth Century-Fox Film Corp.*, Hollywood, Calif.

Offering a means for cutting costs of production and fitting admirably in the picture of modern streamline equipment, the new Twentieth Century Silenced Camera recently made its official debut to an assembly of cine-technicians and cameramen. Although the camera was designed primarily to reduce noise, it also embodies many of those conveniences and devices which spell speed and aid in cost cutting.

The camera has been designed and built along new principles and, instead of trying to hold the noise in the camera case or the blimp, the noise has been reduced at its source to the end that the fast-moving reciprocating parts are as light and as small as possible and when assembled yield uniform acceleration and deceleration, with a resultant optimum movement of the film and a reduction in noise-making vibration. This, when coupled with a patented sound insulating mount for the film moving mechanism, reduces the noise output to a level substantially equivalent to the noise level of the best blimped camera available. Other features included in the camera are described in the paper.

Electroöptical Slating and Cueing Device; D. B. Clark, *Twentieth Century-Fox Film Corp.*, Hollywood, Calif.

As a direct result of the necessity of reducing budgets and cutting corners in motion picture production, many labor-saving devices have lately become evident in the studios. Among the more important of these is a new slating device de-

veloped and used by the camera department of the Twentieth Century-Fox studios.

Designed mainly to save time and film and to put bigger and better slates on the film, the device is a complete unit comprising its own optical system, its own illumination, and carries means for mounting various changeable indicia. These are all assembled in a small casing adapted to be swung into and out of a photographing position a few inches in front of the camera lens to slate the film in the camera. When not in use, the device hangs inconspicuously beneath the sunshade, where it is readily accessible for changing the indicia for successive shots and is easily swung into slating position by a simple twist of the wrist by the camera operator. When using the slating device in production, the camera case need not be opened for cueing and marking takes. This is done photographically, and the film ordinarily wasted by needless exposure is saved for use.

One of the novel features resides in the indicia carrier member which is designed to provide a smooth flat field, including the changeable numbers to yield a clean-cut reflection when the indicia are projected upon the film, said carrier member being readily removable from the casing for changing the data.

In operation the device is swung into a photographing position within the sunshade directly in front of the camera lens before the camera starts turning and, since the device itself blocks off all light except the illuminated indicia, the first frame of the slate can be used as a synch. mark or a cue mark. Under this arrangement, the slating indicia would be photographed on the film while the camera was coming up to speed, thus saving film which is ordinarily lost. Provision is made for operating the illuminating light either from a battery or the 220 a-c that drives the camera motor, the light being controlled by a switch that automatically cuts in as the device is moved into a photographing position.

Photoëlectric Method of Rating the Light-Speeds of Lenses; D. B. Clark, *Twentieth Century-Fox Film Corp.*, Hollywood, Calif.

Photographers and cinematographers have realized for some time that something was wrong with the present method of calibrating light-stops on lenses. As various makes of lenses were interchanged on shots throughout the making of a motion picture, it became more and more obvious that the *f*/ rating did not represent a true value of the light-transmitting capacity of the lens. As a result the real tough job of a cameraman has been to match negative densities in a procession of shots that have been made on lenses of different makes, different focal lengths, and different stops. Even though the lenses are rated as to light-speed and calibrated under the *f*/ system, it is still a guessing game, since some of these ratings are as much as one hundred per cent in error when reduced to actual transmitting capacity of the lens. Since the *f*/ system is the only system used at present for rating the light-speed of lenses, cameramen have been forced to use this system but have found that it is merely a guide and can not be depended upon where accuracy is required. In view of all this, it is believed that a system for rating the light-speed of all lenses based upon actual light transmitted through the lens, regardless of make, size, or any other physical characteristic of the lens, should be of value not only to lens makers, to give them a reading on the overall efficiency of the lens, but also to the cinematographer, to give him an actual effective rating as to the light-valving capacity of the lens.

Such a system has been used in rating all lenses in the camera department of this studio. Disregarding all physical dimensions or characteristics, each lens in the department was calibrated according to the actual value of effective light transmitted with respect to a predetermined reference base. The reference base was established by measuring the effective light transmitted through a 35-mm lens set at $f/3.2$, the source of light being a uniformly lighted field of fixed intensity. This same field was used as the source of light for all lens calibrations. The result was a lens system wherein a light-speed rating represents the same amount of light regardless of make or size of the lens and where the different light-stops on the different lenses indicate a true proportional value of the basic light.

A New Treatment for the Prevention of Film Abrasion and Oil Mottle; R. H. Talbot, *Eastman Kodak Co.*, Rochester, N. Y.

A new type of lacquer has been devised which may be simply and rapidly applied to either one or both sides of 16- and 35-mm films and which may be readily removed in ordinary processing equipment by the use of carbonate solution. The function of the lacquer is to absorb all the ordinary cinch marks and other abrasions commonly found on ciné films which have been in service in the trade. Tests in the field have indicated that the lacquer is somewhat more resistant to abrasion than are the normal film surfaces. When the lacquer has been removed and replaced with a fresh coat, the film is found to be in essentially as good condition as when new. The lacquer is useful in protecting negatives, master positives, duplicating negatives, and prints from all ordinary abrasions. In addition, the lacquer because of its glossy surface eliminates the mottle or flicker on the screen due to oil on the film.

Report of the Committee on Preservation of Film; J. G. Bradley, *Chairman.*

A statement of the work of the Committee as a whole and individual reports of sub-committees on the following subjects: (1) handling and winding of film; (2) safe and economical storage, size of vent per unit weight of film determined, microfilm testing methods developed; and (3) printers for old and shrunken film.

Production Quality Sound with Single System Portable Equipment; D. Y. Bradshaw, *March of Time*, New York, N. Y.

The *March of Time* requires equipment of great portability and simplicity of operation, yet retaining good quality. By using Class *B* push-pull, variable-area recording, a complete noise-reduction sound system weighing fifty pounds was obtained. This single system was used in production of the feature picture *The Ramparts We Watch.* Problems arise from (*1*) recording on panchromatic negative, (*2*) lack of control over negative processing, (*3*) instability of recording unit caused by rough use of camera on which it is mounted, and (*4*) distortion due to lateral track shift. Means for overcoming these handicaps sufficiently have been found. Single system can be used without great sacrifice in quality, where time and space are factors.

Some Laboratory Problems in Processing 16-Mm Sound with Black-and-White and Color Films; Wm. H. Offenhauser, Jr., *Precision Film Laboratories*, New York, N. Y.

The duplication of 16-mm films involves many relatively intricate problems not encountered in the laboratory processing of 35-mm sound-films. These problems have given rise to procedures and apparatus radically different from those in use in 35-mm.

The two major differences that are especially significant are (*1*) the use of reversal for original films; (*2*) the existence of but one row of sprocket-holes on the 16-mm sound-film.

It is interesting to note that all our present standards in 16-mm blindly assume the negative-positive method of operation, ignoring entirely the reversal and Kodachrome. At the present time even the emulsion position of the 16-mm film is standardized on the basis of a 35-mm sound negative and 35-mm picture negative as originals. As a result, our 16-mm dimensions so derived from 35-mm are inconsistent with the projector dimensions at present in use, and inconsistent with the pressing needs arising from the direct 16-mm field.

Much of the difficulty arises from the rather obvious lack of concern displayed by the 35-mm entertainment industry and the very rapid simultaneous growth of direct 16-mm in educational and industrial applications especially in connection with the duplication of sound on Kodachrome.

Some of the special processes and special apparatus features involved are described which have made possible workable solutions to the problems involved.

Reduction of Sprocket-Hole Modulation in Film Processing; M. Leshing, T. Ingman, and K. Pier, *Twentieth Century-Fox Film Corp.*, Hollywood, Calif.

One of the contributing factors to sound-track degradation is sprocket-hole modulation. This is probably more commonly known as 96-cycle modulation and results from non-uniform action of developer around the perforation holes during the time of processing. Its chief remedy is turbulation.

The practical aspects of controlling the amount of sprocket-hole modulation is described herein. Curves showing the increase of this distortion due to diminished turbulation are included as well as those showing the intermodulation of recorded sound by sprocket-hole agitation. Photographs showing various types of sprocket-hole modulation are also presented. There are also shown samples of modulation contributed by developing machines through mechanical defects, such as pressure created by binding rollers and mechanical frictions introduced in the processing machine proper. A complete description of the turbulation methods employed at the Film Laboratory of Twentieth Century-Fox Film Corporation at Hollywood is disclosed and the various sensitometric means of control relative to this problem are given.

Some Observations on Latent Image Stability of Motion Picture Film; K. Famulener and E. Loessel, *Agfa Ansco Corp.*, Binghamton, N. Y.

The observations reported are the result of an investigation to determine definitely the effect of a delay between the exposure and development of modern motion picture films. The stability of the latent image in terms of speed, gradation, graininess, and color response has been studied.

In general, a definite speed increase was noted on negative emulsions, a decrease on positive emulsions. There were also changes in gradation and graininess. The detailed findings, which vary considerably with the individual emulsion type

are given, followed by a general discussion and interpretation of the results. A brief review of the literature is included.

Fixing Baths and Their Properties; J. I. Crabtree, H. Parker, and H. D. Russell, *Eastman Kodak Co.*, Rochester, N. Y.

In addition to removing the unreduced silver halides from an exposed and developed emulsion, the fixing bath should (*a*) arrest development immediately, and (*b*) harden the gelatin film so as to prevent excessive swelling during washing and reduce mechanical injury during handling.

The fixing agent usually consists of sodium or ammonium thiosulfate, or a mixture of sodium thiosulfate with ammonium chloride. The bath also contains an acid (usually acetic acid) to arrest development, sodium sulfite which inhibits the precipitation of sulfur, and potassium or chrome alum which tans the gelatin.

The addition of developer carried into the fixing bath tends to cause the precipitation of aluminum sulfite but this can be prevented by (*a*) revival of the bath with acid at intervals, or (*b*) the addition of boric acid which also extends the *p*H range over which effective hardening is obtained. The exhaustion point at which revival should occur may be determined with *p*H indicators.

Various fixing bath formulas are included and their properties discussed in terms of (*a*) developer capacity, (*b*) sludging and scumming propensity, and (*c*) hardening life.

The Effect of Developer Agitation on Density Uniformity and Rate of Development; C. E. Ives and E. W. Jensen, *Eastman Kodak Co.*, Rochester, N. Y.

A number of essentially different methods of developer agitation of interest in motion picture work have been studied experimentally. In one case the film was held against the inside wall of a conduit through which the developer was pumped at predetermined velocities so as to maintain the required conditions of turbulent flow. By mounting a loop of film on a pair of rollers, the effect of variation in running speed of the film was studied. Tests were made of the effectiveness of liquid jets and also of wringers and scrapers for periodic renewal of developer at the emulsion surface. In order to determine the relative importance of different degrees of developer agitation and of developer renewal by the process of unaided diffusion, the rate of development was varied widely by adjustment of the developer formulas.

Negative Exposure Control; D. Norwood, Hollywood, Calif.

It would be desirable to have negative exposure control on the basis of an exact science. Toward this end the functioning of the human eye as it views a photo subject, and then the photographic reproduction of the subject, is studied. The brightness of the photo subject is broken down into its components of reflectance, a constant, and incident illumination, a variable. The mechanism of the eye acts to compensate for changes in the variable incident illumination. Recognition of the tone of the object is based on its fixed property of reflectance. It is this constant that determines the print density used to portray the object. Between the subject's fixed reflectance and the print's fixed density lies the variable of negative density. A system is proposed whereby a given reflectance in the subject is repre-

sented by a fixed density in the negative. Many advantages derive from this system. Operation of the system involves negative exposure control by means of measurement of incident light. Measurement of effective incident illumination is best accomplished by means of a photoelectric meter specifically designed to respond to the three dimensional characteristics of incident illumination. The system described is free from many of the influences which tend to cause undesirable variations and errors in negative exposure. It provides a means of putting negative exposure control on the basis of an exact science.

Hollywood's Low-Temperature Sound-Stage; R. Van Slyker, Los Angeles, Calif.

The California Consumers Corporation, of Los Angeles, set aside one of its large ice storage buildings to introduce to the studios a new method of making realistic snow scenes.

The purpose of the ice storage building was to furnish a low-temperature sound-stage, where water ice could be used for snow, and enable the casts breath to become visible, as actually occurs in cold or wintery climates.

Snow is manufactured on the low-temperature sound-stage by means of specially constructed portable blowers, grinding 50-pound blocks of ice and expelling through suitable nozzle a fine, aerated snow, directed to the set where and when needed.

The introduction of Technicolor to the low-temperature sound-stage created many new problems in ventilation, due to the low temperature of the atmosphere and quantity of air movement needed to remove gases and smoke from the stage during shooting periods.

The unusual heat load requirements necessitated the construction of external bunker systems, to augment the existing refrigeration for color production.

This was accomplished by the combined use of water ice and ammonia refrigeration in these bunkers, giving a total refrigerating capacity of approximately 650 tons in the system to chill 64,000 cfm of fresh air to 20 °F.

NBC Television Covers the Republican National Convention of 1940; H. P. See, *National Broadcasting Co.*, New York, N. Y.

Television transmission facilities were installed at the Republican National Convention of 1940 held at Convention Hall, Philadelphia, June 24th to 28th. This marked the first time that a news event of national importance, transpiring at a point greater than twenty-five miles distant from New York City, was successfully televised and viewed by NBC's television audience in the New York Metropolitan Area. Program transmission was continuously maintained during each of five daily sessions. These transmissions totaled thirty-three hours and seventeen minutes.

This paper describes the method by which the National Broadcasting Company originated the television pictures at Philadelphia and transmitted them through the facilities of the Bell System to New York, where they were radiated from Station W2XBS, the television transmitter atop the Empire State Building tower. The signals from New York were received by the General Electric Company by means of a specially constructed receiving system near Schenectady and re-transmitted on Station W2XB to the television audience in that vicinity. The audi-

ence consisted of approximately 40,000 persons scattered throughout New York, New Jersey, and Connecticut.

The equipment and its functions are described. Reference is made to the mode and continuity of operation as distinguished from newsreel participation at the same event.

Problems in Television Image Resolution; C. F. Wolcott, *Gilfillan Bros., Inc.*, Los Angeles, Calif.

This paper is primarily thought-provoking, and states problems involved in the consideration of suitable standards now before the National Television Systems Committee.

Resolution is discussed from a standpoint of the number of lines and fields within the limits of presently assigned channels. Related problems touched upon are flicker frequency *vs.* illumination, and some of the difficulties which must be guarded against with colored images, such as raster displacement occasioned by superimposed extraneous magnetic fields or voltages.

The effects of motion, which tend to smear detail, are discussed in relation to frame and field frequency.

The major limitations of present scanning-spot shape and intensity distribution, which determine the vertical and horizontal widths of confusion, have been removed in the laboratory, introducing the possibility of markedly improved definition with a given number of lines and fields which must be reckoned with in determining standards.

SOCIETY ANNOUNCEMENTS

1940 FALL CONVENTION AT HOLLYWOOD

Details of the Convention to be held at Hollywood, October 21st–25th, are given in the preceding section of this issue of the JOURNAL. Members of the Society are urged to make every effort to attend as a very interesting program is being arranged and a number of studio visits and other attractions of a technical as well as entertaining nature are being planned.

PROPOSED AMENDMENTS OF THE BY-LAWS

In the preceding issue of the JOURNAL (September, p. 323) were published several proposed amendments to be acted upon by the Society at the approaching Hollywood Convention, October 21st.

With respect to the proposed By-Law XI, Sec. 4, relating to officers, an inaccuracy in the wording makes it advisable to repeat the amendment in its correct form, *viz.:*

BY-LAW XI, SEC. 4, OFFICERS

Present Wording.—Each Section shall nominate and elect a chairman, two managers, and a secretary-treasurer. The Section chairman shall . . . .

Proposed Wording.—The officers of each Section shall be a chairman and a secretary-treasurer. The Section chairmen shall automatically become members of the Board of Governors of the General Society, and continue in that position for the duration of their terms as chairmen of the local sections. Section officers shall hold office for one year, or until their successors are chosen.

MID-WEST SECTION

The first meeting of the season of the Mid-West Section was held on September 10th at 8 P. M. at the meeting rooms of the Western Society of Engineers, Chicago. Mr. Karl Brenkert of the Brenkert Light Projection Company presented a paper on "The New Brenkert *80* Motion Picture Projector." The projector was described in detail and demonstrated.

The meeting was well attended and plans are being made for an interesting series of presentations during the winter season.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

BAKER, H. W.
International Projector Corp.,
92 Gold Street,
New York, N. Y.

BECKMAN, C.
1333 Bay Ridge Parkway,
Brooklyn, N. Y.

BERGMAN, L. V.
732 Eastern Parkway,
Brooklyn, N. Y.
BLOEDEL, W. H.
828 N. Vista St.,
Hollywood, Calif.
CHAMBERS, I. M.
629 N. Laurel Ave.,
Los Angeles, Calif.
CROSS, W. E.
2918 Pennsylvania Ave.,
Detroit, Mich.
DEAN, C. E.
5825 Little Neck Parkway,
Little Neck, L. I., N. Y.
DELLAGE, C. J.
Box 143,
Eldora, Ia.
DUCHARME, M.
3420 Fullum St.,
Montreal, P. Q., Canada.
FALCONER, R. H.
235 Baker Library,
Hanover, N. H.
GLASS, P.
156 West 105th St.,
New York, N. Y.
GUSS, P. S.
142 East 1st South St.,
Salt Lake City, Utah.
HOWARD, L. W.
525 W. Center St.,
Anaheim, Calif.
KELLNER, C.
2375 East 16th St.,
Brooklyn, N. Y.
KERMAN, E. W.
1447 Cory Drive,
Dayton, Ohio.
LEVINE, H.
138—28 78th Drive,
Kew Gardens, L. I., N. Y.
PETTUS, J. L.
4905 East 13th St.,
Indianapolis, Ind.
PRATER, J. R.
Congress Theater,
Palouse, Wash.
ROGERS, D. C.
162 West 54th St.,
New York, N. Y.
SCHNEIDER, A. F.
640 University St.,
Springfield, Mo.
SCHOMACKER, M. T.
2045 Foxhills Drive,
West Los Angeles, Calif.
SHUEY, C. W.
2506 W. 81st St.,
Inglewood, Calif.
SIEVERS, E. S.
1461 Allison Ave.,
Los Angeles, Calif.
WADDELL, D.
164 Broadway,
Bangor, Maine.

In addition, the following applicants have been admitted to the Active grade:

CARLSON, F. E.
Engineering Department,
General Electric Company,
Nela Park,
Cleveland, Ohio.

CHONG, J. B.
1217 Taft Bldg.,
Hollywood, Calif.
HARSHBARGER, W. J.
R. D. No. 1, River Road,
Somerville, N. J.
HULL, G. F.
2355 Morris Ave.,
Bronx, N. Y.
MUNSON, A. L.
4246 Deyo Ave.,
Congress Park, Ill.

WING, F. M., JR.
245 West 55th St.,
New York, N. Y.

Statement of the Ownership, Management, Circulation, *Etc.*, Required by the Acts of Congress of August 24, 1912, and March 3, 1933, of *Journal of the Society of Motion Picture Engineers*, published monthly at Easton, Pa., for October 1, 1940.

State of New York }
County of New York } ss.

Before me, a Notary Public in and for the State and County aforesaid, personally appeared Sylvan Harris, who, having been duly sworn according to law, deposes and says that he is the Editor of the *Journal of the Society of Motion Picture Engineers* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), *etc.*, of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Name of— *Post Office Address—*

Publisher, Society of Motion Picture Engineers, Hotel Pennsylvania, New York, N. Y.
Editor, Sylvan Harris, Hotel Pennsylvania, New York, N. Y.
Managing Editor, Sylvan Harris, Hotel Pennsylvania, New York, N. Y.
Business Manager, Sylvan Harris, Hotel Pennsylvania, New York, N. Y.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given).
Society of Motion Picture Engineers, Hotel Pennsylvania, New York, N. Y.
E. A. Williford President, 30 East 42nd St., New York, N. Y.
J. Frank, Jr., Secretary, 356 W. 44th St., New York, N. Y.
R. O. Strock, Treasurer, 35–11 35th St., Astoria, Long Island, N. Y.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state).
None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is: (This information is required from daily publications only).

SYLVAN HARRIS, Editor, Business-Manager.

Sworn to and subscribed before me this 21st day of September, 1940.

(Seal) Wm. J. Miller.
Notary Public, Clerk's No. 412, New York County. Reg. No. 2M 286

(My commission expires March 30, 1942)

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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COMMERCIAL MOTION PICTURE PRODUCTION WITH 16-MM EQUIPMENT*

JOHN A. MAURER**

Summary.—*Improvements in film characteristics together with progress in film laboratory technic and in 16-mm sound recording during the past few years have made it possible to produce sound motion pictures directly on 16-mm film with both picture and sound quality comparable to the results obtained in the past by optical reduction from 35-mm negatives, and at considerably reduced cost. This method is of special value in the production of training films and other types of industrial and educational motion pictures requiring much of the photography to be done away from studio facilities.*

This paper discusses the apparatus available for direct 16-mm production, the film types that are in use, the film laboratory services that are available, and the methods that are used by direct 16-mm producers in the cases where these methods differ from those of the 35-mm producer. Particular attention is given to the Kodachrome process as used in commercial motion picture production.

The use of 16-mm prints for the projection of industrial and educational motion pictures has today become almost universal. In these non-theatrical applications of motion pictures the superior convenience and economy of 16-mm equipment made inevitable the displacement of larger film sizes. At the same time these advantages have made possible the employment of films in business and in the schools on a much wider scale than would have been possible with previously existing films and equipment.

Production of school and business films directly in the 16-mm size is a development that has come much more slowly. Most of these subjects are still photographed on 35-mm film even though, as a rule, they are intended for projection only in the 16-mm size.

During the past few years, however, rapid technical progress has

* Presented at the meeting of the Atlantic Coast Section January 10, 1939; revised and re-presented at the 1940 Spring Meeting at Atlantic City, N. J.

** The Berndt-Maurer Corp., New York, N. Y.

stimulated an already active interest in the possibilities of direct 16-mm picture photography and sound recording, with the result that numerous film subjects have been produced entirely with 16-mm equipment. Those who are familiar with the present results of this activity believe that direct 16-mm production holds the possibility of another considerable extension of the field of usefulness of non-theatrical motion pictures.

A correct appraisal of the value of equipment or methods in any field requires a knowledge of the type of service for which they are intended. In considering direct 16-mm motion picture production it is particularly important to have clearly in mind the proper scope of 16-mm production activities. It has been pointed out that the two factors of convenience and economy are mainly responsible for the present wide use of 16-mm films and projectors. In production the use of direct 16-mm equipment will be desirable in proportion to the extent to which greater convenience and lower cost are obtained without undue sacrifice of quality.

Certain types of industrial films, notably sales films designed to appeal to large audiences, require elaborate studio facilities and expensive acting talent. In the budget of such a film the cost of photography on either 35-mm or 16-mm film is a decidedly minor item. Therefore in this field there is nothing to be gained by the use of 16-mm equipment. In the production of training films, on the other hand, most of the photography must be done "on location" in the actual manufacturing plant, mine, or laboratory. Here the cost of photography, including the costs of film and processing, the time of the camera crew, and the cost of any interference with plant production, is the principal cost of the film, and here the savings effected by 16-mm operation become important.

Convenience has two aspects, its inherent desirability and its effect upon costs. A 35-mm camera adequately equipped even for newsreel work is necessarily large enough and heavy enough that it is by no means easy to move around with it. A magazine case containing two or three reels of film loaded and ready for use is all that the average man would be interested in carrying for any distance. By comparison a 16-mm camera and its supply of film are extremely easy to handle. These differences in size and weight make it possible to handle 16-mm equipment more rapidly, with the result that location filming can be accomplished in a considerably shorter time than is required when using 35-mm cameras.

A similar situation exists when a sales film is being produced to appeal to a small or highly selected audience on the basis of "the reason why." This type of sales film depends for its effectiveness on the force and timeliness of the ideas presented rather than on elaborateness of treatment, and can generally be produced more quickly, more conveniently, and less expensively by the direct 16-mm method.

The obvious aspect of the economy of working in 16-mm, that is, the lower cost of film and processing, is usually the least important.

FIG. 1. Direct 100-diameter enlargement from 16-mm negative on Cine Kodak Safety Panchromatic Negative Film.

It is true that the ratio of film cost between 35-mm and 16-mm is of the order of 3 to 1. Where pictures are taken for record or study purposes, this difference frequently means that a project can be carried out with 16-mm equipment, whereas it would be prohibitively costly in 35-mm. But in general the cost of film itself is unimportant in comparison with the savings that result from using 16-mm equipment because of its greater mobility, its ability to turn out more work in a given time, and lower handling and transportation costs.

The safety of the 16-mm film itself is another important advantage when production work is being carried on in school or factory. The

fire-proof storage vaults and projection rooms required for working with 35-mm film are not only expensive, they are also inconvenient, and in many cases impossible to install. This fact alone permits many institutions to engage in 16-mm film production when 35-mm production would be out of the question.

It should be recognized that in the past there have been technical reasons for preferring to photograph in the 35-mm size that have outweighed considerations of cost and convenience. With the ma-

FIG. 1(*a*). Enlargement of entire frame corresponding to Figs. 1, 3, *etc.*, showing the portion enlarged to 100 diameters in these figures.

terials available ten years ago, and even five years ago, it was impossible to turn out 16-mm prints from 16-mm originals with picture quality good enough to be satisfactory in comparison with pictures photographed on 35-mm film and optically reduced. Excellent picture quality was obtained, of course, on original reversal films. Processes of duplication, however, left much to be desired. Direct 16-mm negatives gave images that were far too grainy to be acceptable. In addition, the physical properties of the acetate film base introduced limitations which will be discussed later in this paper. Furthermore, the equipment and film laboratory services existing in the 16-mm

field during this period were not adequate for the needs of commercial film producers.

In view of the fact that the removal of these limitations having to do with the film is the principal reason for the present increase of 16-mm activity, this is probably the best point at which to begin a general study of the methods and tools that are being used by direct 16-mm producers.

It is a matter of general knowledge that an astonishing improvement in film emulsion characteristics has taken place during the past

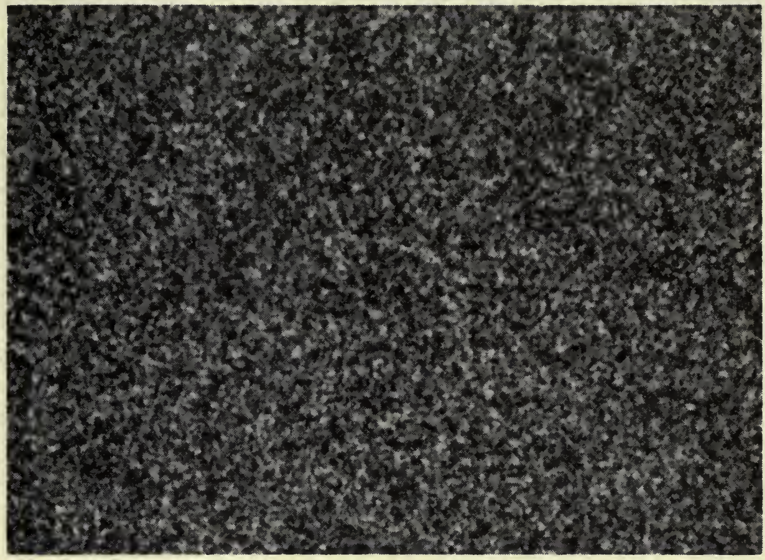

FIG. 2. 100-diameter enlargement of small portion of sensitometric strip on Eastman Positive film (Type *5301*).

three years. Increases of speed have been well advertised. The improvement in grain structure that has been obtained in materials of less sensational speed has also been well advertised, but has perhaps received less general attention. This reduction in graininess has completely changed the situation that formerly existed when comparing prints from 16-mm negatives with those made by optical reduction from 35-mm negatives.

In the past, most of us have been in the habit of thinking of standard positive film as a fine-grained material. It will possibly surprise many workers in the industry to learn that today high-speed negative

films are available that are capable of yielding images actually finer in grain structure than those of standard positive film.

Figs. 1 to 4 show some of these graininess relationships. Fig. 1 is a direct 100-diameter enlargement of a small portion of a 16-mm negative made on Ciné Kodak Safety Negative Film of the type being marketed at the present time. (This film appears to have practically the same emulsion as Background *X* 35-mm film.) Fig. 2 is another 100-diameter enlargement showing the grain structure of a strip of

FIG. 3. 100-diameter enlargement of print from negative of Fig. 1 on Eastman Positive film (Type *5301*).

positive film exposed and developed to a density matching the face tones in Fig. 1. Fig. 3 shows a contact print from the negative shown in Fig. 1 on film of the type shown in Fig. 2.

By comparing Figs. 1, 2, and 3 it may readily be seen that the grain of the positive printing stock has contributed at least as much to the appearance of graininess in the print as the grain of the negative.

In optical reduction printing the grain structure of the negative is reduced approximately $2^1/_2$ diameters, and also it is usually diffused because of lack of perfect definition in the lens system of the printer

to such an extent as to be practically lost. In an optical reduction print, therefore, almost all of the effect of graininess is due to the positive stock.

Fig. 4 is a 100-diameter enlargement of a small portion of an optical reduction print, chosen because it contains flesh tones closely matching those of Fig. 3 in density. It will be noted that the graininess of the image in Fig. 4 is practically the same as that in Fig. 3. This demonstrates the relative unimportance of the 16-mm negative

FIG. 4. 100-diameter enlargement of optical reduction print on Eastman Positive film (Type *5301*).

as a source of grain, and shows why it is now possible to obtain contact prints from 16-mm negative that compare well with prints made by optical reduction from 35-mm negatives.

The negative-positive process has been used as the example to show the present improved state of film emulsion characteristics because it is the most nearly comparable to the usual 35-mm procedure, and because, in the past, it has been the least satisfactory of all ways of obtaining 16-mm picture prints. Other procedures which the writer believes to be more generally desirable will be discussed later in this paper.

A wide variety of camera types is today available to the 16-mm producer. These may be classified roughly as (*1*) spring-driven amateur cameras, (*2*) motor-driven and otherwise specially equipped amateur cameras, and (*3*) cameras primarily designed for professional use.

Cameras of the first class are by no means useless in commercial work. Used intelligently, all those of reputable make are capable of meeting all normal requirements as to steadiness and sharpness of

FIG. 4(*a*). An enlargement of the pianist's left hand is shown in Fig. 4.

pictures. Since their motive power is self-contained, and they require for an average day's operation no more film than can be carried in the cameraman's coat pockets, they lend themselves especially well to the filming of industrial plant operations, where it is generally important to get the picture without interfering with production. Among the most desirable types are the magazine-loading cameras, which offer the extreme in small size and convenience.

The most serious limitation of the typical amateur camera is the inaccuracy of its finder. These finders are generally adjusted to be correct for a distance of fifteen feet. At other object distances errors

of parallax enter which are especially troublesome when lenses of longer focal length than the customary one inch are in use. In the Ciné Kodak Special this limitation is largely removed by the provision of a reflex focusing mechanism which permits viewing the actual image of the lens that is in taking position. It is probably for this reason that the Ciné Kodak Special has been more widely used for commercial motion picture production than any other 16-mm camera.

A good example of the second class of camera is the Bell & Howell Filmo equipped with synchronous motor drive and external 400-foot film magazine. These attachments make the camera usable for synchronous picture and sound-recording work, although it is usually

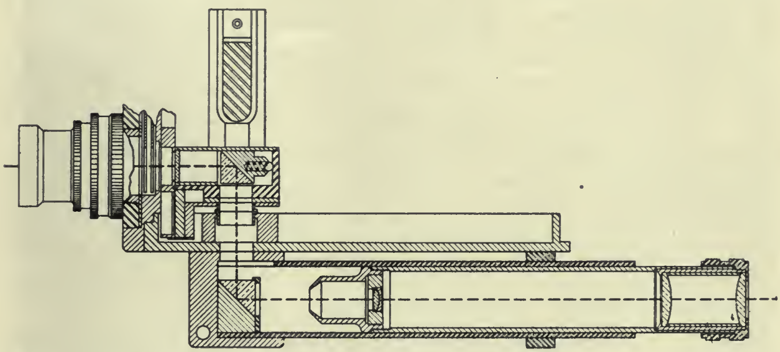

FIG. 5. Horizontal sectional view of part of Berndt-Maurer "Sound-Pro" camera, showing method of focusing on ground glass.

necessary to enclose the entire mechanism in a "blimp" in order to make it quiet enough for operation near a microphone. Motor drives, both synchronous and non-synchronous, are also available for the Ciné Kodak Special. This camera likewise requires some form of sound-insulating enclosure when it is to be used near a microphone.

Among the numerous accessories that are available for use with the Ciné Kodak Special, the auxiliary finder, adjustable for parallax, and the focusing microscope attachment deserve special mention. Because these attachments increase the accuracy with which the camera can be used, they are generally employed by cameramen doing commercial work with the "Special."

Aside from the fundamental ability to produce steady pictures, the most important requirements of a camera for professional work

are accurate finding and focusing. All the cameras that have found extensive use in 16-mm commercial production have provision in some form for focusing on ground glass. In the Bell & Howell Filmo this is accomplished by rotating the lens turret so as to bring the lens in front of a ground-glass which is viewed through a magnifying lens and reflecting prism. In order to focus the Ciné Kodak Special a first-surface mirror is introduced between the lens and the shutter, thus reflecting the image to a ground-glass screen viewed either directly through a magnifying lens or indirectly through the microscope attachment referred to above. This system has the important advantage that it avoids moving the lens from its operating position. In the Magazine Ciné Kodak a microscope unit can be substituted for the magazine of film, thus making possible very accurate focusing and composition of the subject in the picture area.

In the Berndt-Maurer "Sound-Pro" camera, which is designed primarily for professional use, these provisions for accurate focusing and picture composition are carried out with maximum accuracy. The focusing system is shown in Fig. 5 and Fig. 6. Picture-gate and pull-down mechanism are mounted on a dovetailed slide which also carries a separate focusing aperture covered with fine ground glass. For focusing, this slide is moved laterally so as to bring the focusing aperture to the lens axis. In this position the ground glass is viewed through a microscope magnifying eight diameters.

The regular finder of the Sound-Pro camera shown in Fig. 7 is of the inverting prism type, the image being formed on a ground glass, accurately framed. The image is right side up and correct as to left and right. The finder is adjustable for parallax, and contains internal adjusting features by which the field it shows can be made to correspond accurately to the actual field of the taking lens, even though the latter is not perfectly centered in its mount, a not uncommon condition.

Since most industrial and educational pictures today are produced with sound, quiet operation is a necessity in a professional 16-mm camera. Since this was not an objective in the design of the amateur types, it is necessary to "blimp" them when they are to be used for pictures synchronized with sound. It may be doubted whether the degree of silence in operation that is required for synchronous studio operation can be obtained without extreme mechanical precision in the construction of the camera. This necessarily makes the truly professional instrument much more costly than the amateur types.

Fortunately for the convenience of the producer, the majority of industrial and educational motion pictures are most effective when the sound takes the form of spoken commentary with background music or sound effects. This type of sound accompaniment is, of course, scored after the picture has been completely photographed and edited. Under these conditions a quiet running camera is not needed.

Although it has now become an easy matter to introduce fades and dissolves in the film laboratory on 16-mm film, the professional cam-

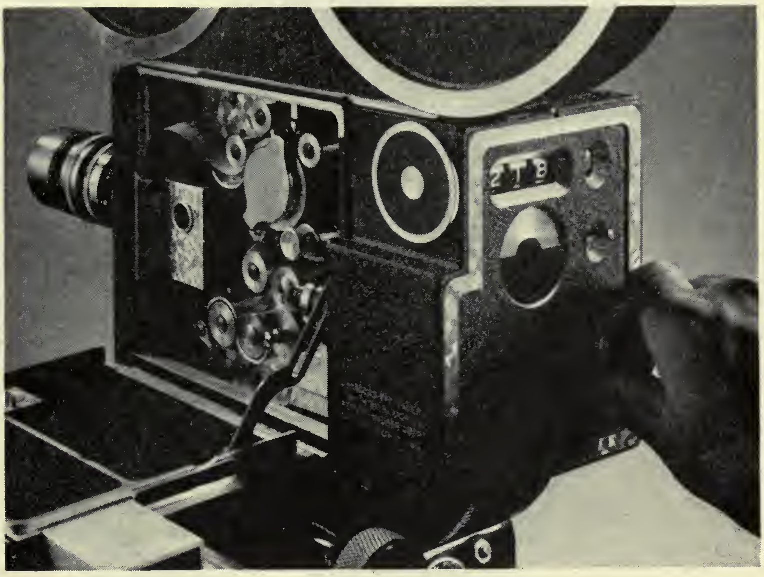

FIG. 6. View of "Sound-Pro" camera with door open, showing gate shifted into focusing position.

eraman naturally wishes to have his camera equipped to produce these effects directly. Both the Ciné Kodak Special and the Berndt-Maurer Sound-Pro cameras are so equipped. In the latter case both automatic and manual shutter controls are provided.

A minor difficulty that sometimes causes annoyance when working with 16-mm cameras is a variation in position of the frame line with different batches of film stock. This can occur in any camera in which there is a distance of several frames of film between the picture aperture and the terminal position of the pull-down claw. The cause is shrinkage of the film stock with age, which produces the frame-line

displacement in the manner illustrated in Fig. 8. The basic remedy consists in designing cameras with the pull-down mechanism as close as possible to the picture aperture. A practical remedy that can be applied by the cameraman is to avoid the use on the same production of film several months old and film that has just been purchased. Film manufacturers could help this situation materially by sealing

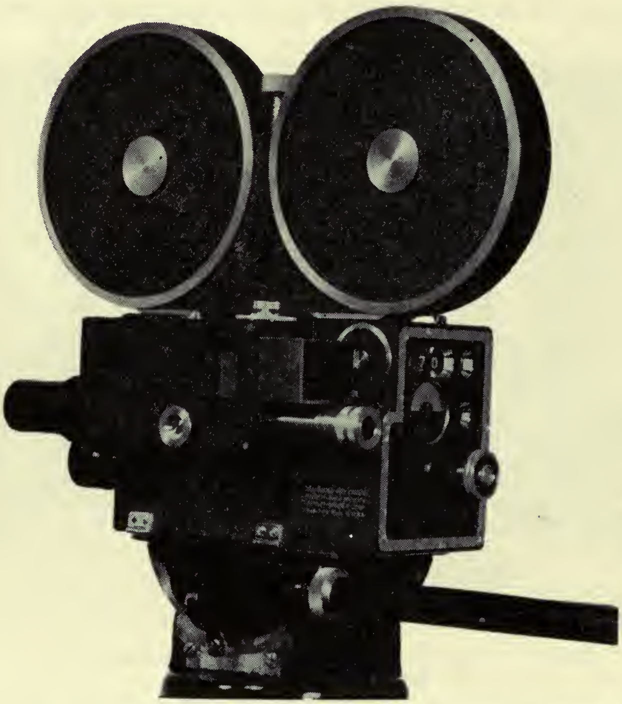

FIG. 7. "Sound-Pro" camera with door closed, showing finder and focusing microscope.

their film containers so as to prevent the escape of moisture and consequent shrinkage of the film with age. This is usually not done in the case of the reversal films now on the market.

Films for 16-mm picture photography naturally fall into three classifications, (*1*) black- and-white reversal films, (*2*) black-and-white negative films, and (*3*) color-films. These, in turn, lead to a considerable diversity of possibilities in the production of copies for distribution. Most of the possible methods have been tried out thor-

oughly in practice, and can be appraised with considerable definiteness.

Well photographed original reversal gives the best picture quality that can at present be obtained on 16-mm film. This quality can be

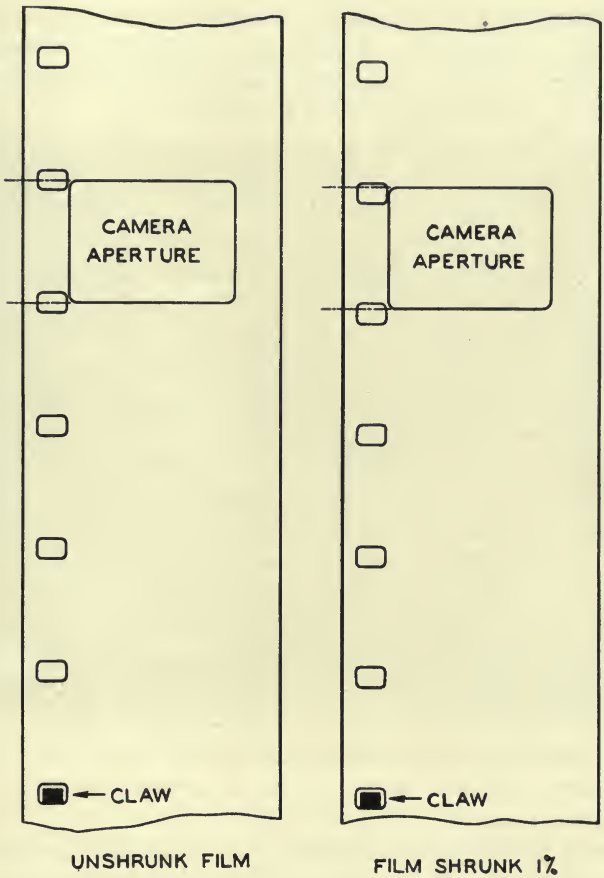

FIG. 8. Diagram drawn accurately to scale, showing how film shrinkage can produce frame-line displacement in improperly designed cameras and printers.

approached in carefully made prints from either 35-mm or 16-mm negatives provided fine-grain film is used for the print, but it can not be equalled by any process known to the writer. Reversal images are characterized by fineness of grain, excellent sharpness of image,

and a clear, sparkling quality that is difficult to match by other processes.

Unfortunately for the professional who is attempting to use reversal films for the first time, most of them require a lighting technic quite different from that which gives the best results with negative films. Reversal films have been developed to satisfy the taste of amateur users, who, as is well known, generally like "brilliant," that is to say, high contrast, results better than the delicate tone gradation for which the professional is likely to strive.

That high contrast is not a necessary property of reversal films is indicated by the fact that one "supersensitive" film which was on the market for several years was of low contrast, and gave excellent long-scale reproduction. This film was withdrawn from the market when it became possible to produce films of both higher speed and higher contrast.

Of the reversal films now on the market the most rapid available, Agfa *SSS* Superpan and Eastman Super *XX* Panchromatic, give the softest tone rendition. In spite of their remarkably high speed, both these films give excellent image quality and are to be recommended as the most generally satisfactory for commercial work.

Because of the somewhat high contrast of even these ultra-rapid reversal films, the professional photographer who is using them for the first time should light his subject rather more flatly than he is accustomed to doing. This does not mean that brilliant backlighting is to be avoided, for the reversal process reproduces this type of lighting unusually well. What is important is to maintain a high level of general illumination relative to the light used for "modeling," so as to avoid excessively dark, empty shadows in the final result. On the other hand, effects of striking contrast, with jet black shadows, when desired, can be obtained better on reversal film than on any other medium.

Copies of pictures photographed on reversal film are being made commercially by two processes: (*1*) reversal duplication, and (*2*) positive printing from an intermediate negative made on fine-grain duplicating film.

Until the appearance of suitable fine-grain film for negative making, reversal duplication was the only satisfactory means of producing copies from reversal originals. The process gives a fine-grain image and good tone rendition, but suffers from two faults. The more serious of these is a tendency to produce a white line, sometimes amount-

ing to a conspicuous halo, around any dark object which stands against a medium gray background. This is a form of the well known "Eberhardt effect." The second defect is a lack of volume in the reproduction of sound-tracks printed on reversal duplicating film. The nature of the reversal process is such that it is very difficult to obtain complete transparency even where the exposure has been very high. This limits the modulation range of both variable-area and variable-density sound-tracks to such a degree that the level ob-

FIG. 9. 100-diameter enlargement of picture on original reversal film.

tained in reproduction is from six to twelve, or in some cases as much as fifteen, decibels lower than is obtained with positive prints from sound-track negatives. This loss of reproduction level is not great enough to make the results unusable, but it does have an undesirable effect on the ratio of signal to background noise obtained with the average 16-mm sound projector.

Because of the above-mentioned faults of the reversal duplicating method, and because it is more costly than the intermediate negative and positive print method, the latter is to be preferred for practically all commercial purposes.

Figs. 9, 10, and 11 will give some idea of the quality that is being obtained commercially in the duplication of reversal originals by means of fine-grain duplicating negative and positive printing stocks. Fig. 9 is a 100-diameter enlargement from an original reversal image of the same subject shown in Figs. 1, 2, and 3. Fig. 10 is a similar enlargement from a negative printed from this reversal original on Eastman type *5203* panchromatic duplicating stock. Fig. 11 shows

FIG. 10. Direct 100-diameter enlargement from negative on Eastman type *5203* fine-grain panchromatic duplicating stock, printed from the reversal original shown in Fig. 9.

a print from the negative of Fig. 10 on DuPont fine-grain positive stock.

A comparison of Fig. 11 with Fig. 4 shows that the reversal-intermediate-negative-positive-print process leads to results that are superior to what might be termed standard optical-reduction prints from the standpoint of fineness of grain, and at least equal to them in sharpness of image. Valid comparisons of tone rendition are practically impossible to carry through the process of reproduction by photoengraving. It is fair to state, however, that the tone rendition of prints obtained in regular commercial practice by this process ap-

proximates that of the reversal originals as closely as is usual in 35-mm duplicating practice. When the original has been slightly under or overexposed, or is either too flat or too contrasty, it is usually possible to make a print from the intermediate negative that will appear much better on the screen than the original itself.

The reversal-intermediate negative procedure for producing prints of 16-mm subjects has several advantages that are not immediately obvious. It safeguards the production in the same manner as the

FIG. 11. 100-diameter enlargement of print from negative of Fig. 10 on DuPont type *3737* fine-grain positive stock.

making of a "lavender" print in 35-mm practice, since the original, after editing, is run through the printer only once to make the fine-grain negative. A practically unlimited number of prints of a subject is possible, since new fine-grain negatives can always be printed from the original. It combines the fine-grain image advantage of reversal photography with the ability to control contrast provided by the negative-positive process. Optical printing effects, such as fades, dissolves, and wipes, are produced directly in the printing of the fine-grain negative, and therefore are not liable to the abrupt changes in picture density or quality, or both, often seen in 35-mm work where

short sections of original negative before and after the effect have been replaced by the duplicate negative carrying the effect. This is one of the major advantages of working from a positive original.

There is a more important reason than all the above, however, for preferring to use reversal film for 16-mm commercial motion picture photography. This is the vastly greater ease and certainty with which reversal positives can be edited, as compared with negative film. Because of the small size of a 16-mm negative, every scratch,

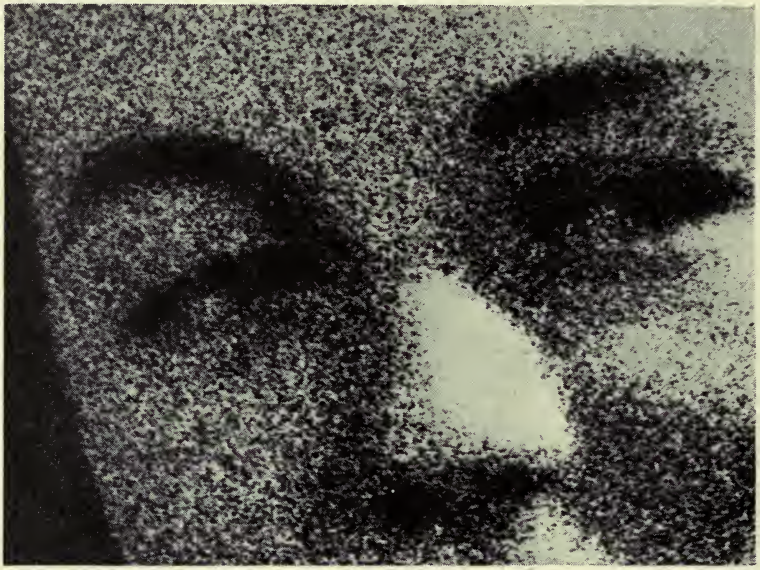

FIG. 12. Direct 100-diameter enlargement from 16-mm negative on Agfa Superpan Supreme, showing grain structure representative of modern extremely rapid films.

and every particle of dirt, impressed on the film during editing, will be objectionably apparent as a white mark on the screen when the positive print is projected. Similar defects in a positive original produce black markings on the final print, and these as a rule are impossible to see on the screen. Splices in a reversal original are seldom noticeable when the print is projected; splices in a 16-mm negative must be made with extreme care if they are not to be conspicuous on the screen. The net effect is that it is relatively easy even for an untrained person to edit a reversal original so as to produce a clean effect when the final print is projected, whereas the editing of a 16-

mm negative requires expert handling under clean conditions if the final result is to be free from mechanical blemishes appearing as white marks or flashes on the screen. This difficulty does not appear in the case of the fine-grain intermediate negative printed from the reversal original because this negative (usually) contains no splices and receives no handling other than is incidental to printing. In the hands of well trained film laboratory personnel such a negative will yield at least fifty prints before becoming noticeably abraded.

In spite of the difficulty of editing 16-mm negatives, a considerable number of producers have preferred to work by the negative-positive process, partly because it reduces film costs to a minimum, and partly because as individuals they were familiar with the photographic technic of negative films and preferred not to attempt the unfamiliar technic of reversal. The results have proved that in spite of the difficulties pointed out above, 16-mm negative-positive is today a useful process.

There are at the present time (August, 1940) four types of negative film available in the 16-mm size. These are Ciné Kodak Safety Negative Film (Panchromatic), Ciné Kodak Super *XX* Negative Film, Agfa Superpan Supreme, and DuPont Superior Panchromatic. The first of these apparently corresponds to Background *X* 35-mm film; the others are similar in properties to the 35-mm negative films of the same name.

The graininess characteristics of the slowest of these films (Ciné Kodak Safety Negative Film) have already been indicated in the 100-diameter enlargements, Fig. 1 and Fig. 3. Figs. 12 and Fig. 13 show the graininess characteristics of Agfa Superpan Supreme, which is representative of the three faster films. While the reader will notice that the graininess of this negative and print is considerably greater than that shown in Figs. 1, 3, 9, 10, and 11, it should be pointed out that in actual practice the degree of graininess shown in Fig. 13 has not been found objectionable. It is probable that more 16-mm commercial productions have been photographed on this film than on any other of the negative types, and of these several have had wide distribution. (One of the pictures projected at the Atlantic City convention in April as an example of 16-mm negative-positive work was a commercial production made on Agfa Superpan Supreme.)

For best results these 16-mm negative films require fine-grain processing. The DuPont Superior film has for several years been

processed by the manufacturer in a paraphenylene-diamine developer. At the Precision Film Laboratories, in New York City, where the test-films used for the illustrations in this paper were processed, a different type of fine-grain developer, suitable for use in machine development, has been evolved. The results shown in the enlargements are, therefore, not typical of what is obtained with rack-and-tank processing in conventional developers.

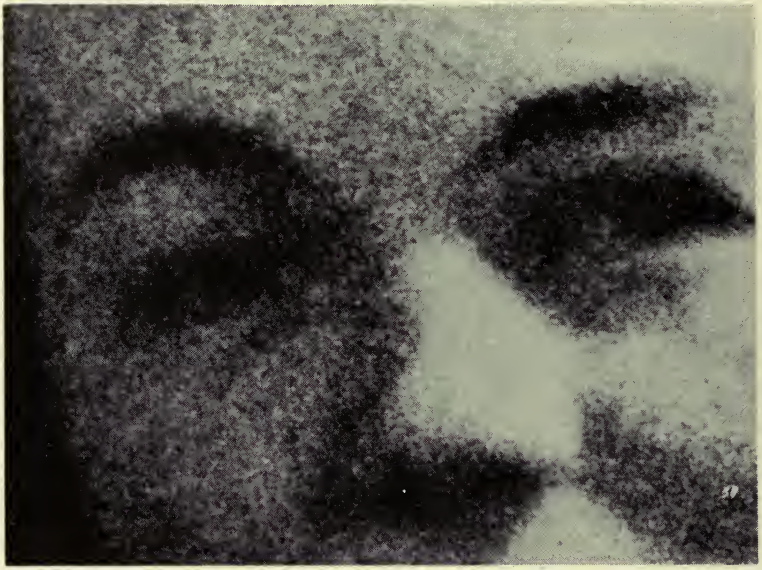

FIG. 13. 100-diameter enlargement of print of negative shown in Fig. 12 on Eastman Positive film (type *5301*).

It has already been pointed out that the conventional types of 16-mm positive printing stock, such as Agfa type *220*, DuPont type *600*, and Eastman type *5301*, contribute materially to the graininess of either 16-mm contact prints or optical reduction prints from 35-mm negatives. Therefore the introduction of a fine-grain positive printing stock, DuPont type *3737* (corresponding to the 35-mm type *222*), was of unusual significance to the 16-mm field. The quality of prints obtained on this stock from the fine-grain intermediate negatives made from reversal originals has already been indicated by Fig. 11. Fig. 14 shows the effect of printing from the negative of Fig.

1 on DuPont type *3737*. This print is only a little more grainy than the print of Fig. 11, and considerably less grainy than the conventional optical reduction print of Fig. 4. The improvement in screen quality that is obtained by using this fine-grain positive printing stock is readily apparent to the critical eye, and is the more worth while because a similar improvement in sound-track quality is obtained at the same time.

FIG. 14. 100-diameter enlargement of print of negative shown in Fig. 1 on DuPont type *3737* fine-grain positive film.

The inherent difficulty of editing 16-mm negatives has already been mentioned, but the importance of this point is such that it can hardly be emphasized too strongly. The editing of a production photographed on 16-mm negative film is the step which, more than any other, decides whether or not the final result will be a source of satisfaction to those responsible.

As has been proved by numerous commercial examples, excellent results can be obtained in prints from 16-mm negatives. If, then, the editing is handled as is customary in cutting 35-mm theatrical productions, that is to say, if the picture is first edited by means of work

prints and the negative is then matched to the edited work print by a careful worker, in a room free from dust, with a minimum of handling, and that only with clean gloves on the hands, the final prints may be expected to be clean and free from blemishes. Any scratches, fingerprints, or cinch marks on the 16-mm negative will naturally appear on the screen on a larger scale than they would if they were on a 35-mm negative, but this is somewhat offset by the fact that scratches on the negative print with much lower contrast by contact than when printed on an optical reduction printer.

But while the above is a fair statement of the case, it has happened several times in the writer's experience that the film editing of an otherwise well handled production was entrusted to an inexperienced person, with the result that the negative was almost completely ruined. Too frequent unwinding and rewinding of small rolls of negative, especially in a dusty room, inevitably produce blemishes that can not be removed by any amount of cleaning and polishing. Usually all that is needed to avoid such excessive handling of negatives is a good system of keeping records of the contents of each roll of film.

The two preceding paragraphs amount to saying that the careful worker who knows the precautions necessary in handling negatives will have no difficulty in editing 16-mm negative film. But the inexperienced should stick to reversal, which will tolerate much rougher handling without showing bad effects on the screen.

Even in the case of reversal, a work print should be used for the editing of any production on which much effort has been expended. Such a work print may be made by reversal duplication or, less expensively, it may take the form of a negative printed on ordinary "positive" stock, or of a positive printed from such a negative. No particular care need be required of the laboratory in printing such work negatives or work prints, since the object is only to obtain a recognizable copy of the original for editing purposes.

One of the most important of the factors that have led to the present increase of activity in direct 16-mm motion picture production has been the availability of the Kodachrome process. This, with the perfecting of a satisfactory duplicating procedure, has brought advertising and scientific films in color within the means of the average business firm, school, or college. A large percentage of direct 16-mm productions are today being photographed in color.

A better description of the technic of commercial production in Kodachrome can be given after certain matters pertaining to 16-mm

film laboratory technic and 16-mm sound-recording practice have been pointed out. Therefore this topic, which logically belongs here in our discussion, will be deferred to the end of the paper.

It is desirable to note at this point, however, that Kodachrome lends itself well to the production of pictures that are to be distributed both in black and white and in color. The fine-grain negative duplicating stock referred to above, being panchromatic, produces, from Kodachrome, negatives having pleasing monochrome color rendition and generally satisfactory gradation. Kodachrome, being a reversal process, has very fine grain. As a consequence black-and-white prints from fine-grain negatives made from Kodachrome have the same characteristics as those resulting from black-and-white reversal originals. In fact, scenes taken on Kodachrome may be edited into a picture taken mostly on black-and-white reversal film, and these scenes will not differ noticeably from the others in the final print made from the fine-grain negative. This is often a decided convenience to the film editor.

A factor which has necessarily retarded the development of the direct 16-mm production field has been the lack of suitable printing equipment in film laboratories. This condition still exists in many parts of the country, making it necessary for those to whom quality is important to send their work to laboratories specializing in 16-mm processing.

It has generally been recognized in the motion picture industry that picture printers operating on the step-by-step principle give results superior to those of continuous printers. Nevertheless practically all 35-mm release printing is successfully handled by continuous printers. This fact has led to the construction and use of 16-mm continuous printers, which have in general produced less desirable results. In any continuous hollow-sprocket type of printer there is a certain amount of slippage between the negative and the positive stock except in the rare case when the negative shrinkage is exactly the amount for which the printer sprocket was designed. The amount of this slippage is proportional to the distance between adjacent sprocket-holes and to the range of shrinkage of the film base. In the case of 16-mm films, these values are such that the slippage may amount to as much as 0.0015 inch during the passage of the film in front of the printing aperture. This is enough seriously to impair the sharpness of the image.

On the basis of the reasoning stated above, the writer is convinced

that for the highest quality of 16-mm contact printing it is necessary to use step printers, preferably with pilot-pin registration of the films.

In some of the step-printing machines that are on the market and in practical use, we encounter the same cause of frame-line variation that was discussed in connection with Fig. 6. If there is a distance of several frames between the pull-down and the printing aperture, and if the film being printed consists of sections of different ages and therefore of different degrees of shrinkage, the frame line of the negative will shift from section to section relatively to the frame line of the printer, sometimes greatly to the detriment of the appearance on the screen. As a result of his experience the writer is convinced that for generally satisfactory performance two frames is the maximum distance that ought to exist between the bottom of the aperture and the pull-down claw in either a camera or a printer.

The seriousness of this frame-line difficulty was formerly much greater than it is at the present time. During the past few years considerable improvement in 16-mm film shrinkage characteristics has taken place. This is one of the aspects of the general improvement in films which has contributed to make direct 16-mm picture production a practical commercial undertaking.

While industry still finds a number of uses, such as motion study, for the silent motion picture, the distribution of sound projectors has now become so wide that most industrial and educational pictures are produced with sound. Without direct 16-mm sound-recording equipment, direct 16-mm production would be out of the question.

At the present time both single-system, or newsreel type, and double-system 16-mm sound-recording equipment are available. Because of the limitations which the single-system procedure imposes in editing, however, this type of equipment is little used by commercial film producers and will not be discussed here.

Sixteen-mm sound recorders for double-system operation have been built by the Berndt-Maurer Corp. since the year 1935. Fig. 15 shows the machine at present manufactured. Sixteen-mm recorders are also manufactured in the United States by the Herman A. DeVry Corp., the Canaday Sound Equipment Co., and by the C. R. Skinner Mfg. Co. A variable-density recorder for 16-mm film developed by Electrical Research Products, Inc., was described before this Society at the Detroit Convention in the fall of 1938.[1] The results obtained with the Berndt-Maurer recorder, which uses the variable-area sys-

tem, were described and demonstrated by the writer at the Hollywood Convention of the Society in April, 1939.[2]

Until about the end of the year 1938, practically all 16-mm sound recording was done on the standard positive printing stocks (Agfa type *220*, DuPont type *600*, Eastman type *5301*). Since that time two stocks specifically intended for sound recording have been available. These are DuPont type *601* and Eastman *5359*. Still more recently a yellow-dyed film, Agfa type *250*, has become available.

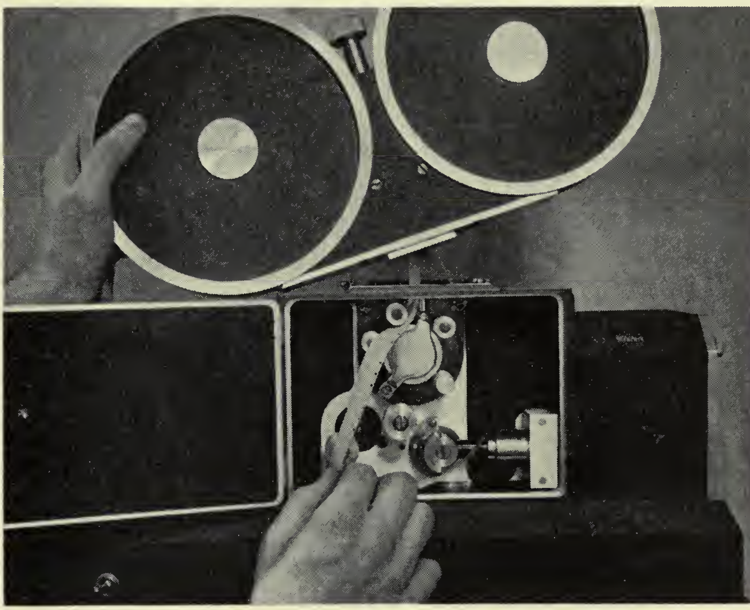

FIG. 15. Berndt-Maurer 16-mm sound recorder.

These newer films, when used in combination with filters to exclude the blue-green range from the recording light-beam, make possible a standard of sound quality on direct 16-mm recordings that is far superior to that commonly obtained in sound-tracks optically reduced from 35-mm negatives. The last-mentioned stock is of exceptionally high resolving power. When sound negatives are recorded on this stock and printed on the fine-grain positive (DuPont type *3737*), both the frequency range and freedom from distortion customarily obtained with 35-mm film can be equalled on 16-mm prints.

In 16-mm sound recording, as in 16-mm picture photography, the quality of the result is principally determined by the processing and printing of the films. Accurate control of density and gamma in development, and printing on high-quality equipment are expected as a matter of course in 35-mm processing. Until the advent of film laboratories specializing in 16-mm processing it was difficult to obtain similarly careful handling of 16-mm sound-tracks. Today producers are aware that results of high quality are possible in 16-mm, and this realization has resulted in their demanding, and getting, a higher standard of work from the entire trade.

It has been stated above that the conventional hollow-sprocket type of continuous printer is not suitable for producing the best quality of 16-mm picture prints. It is entirely unsuitable for 16-mm sound printing. Either a non-slip printer or an optical one-to-one ratio sound-printer so designed as to overcome the effects of shrinkage is a necessity. In the writer's experience the optical sound-printer is the best of all types.

The editing of 16-mm sound and picture films presents no problems that were not solved long ago in 35-mm practice. The conventional "synchronizer," consisting of two sprockets attached to the same shaft (and usually coupled to a footage meter) serves most purposes, since numerous retakes of a scene are not common in 16-mm production. When scenes involving synchronized sound and picture are taken, the clap-stick method of obtaining start marks is generally used. This makes it unnecessary to employ a Moviola. A 16-mm Moviola is available, however.

The majority of 16-mm industrial and educational productions require "off-stage voice," or commentary, rather than synchronized sound. For scoring such sound to match previously edited pictures, it is necessary to have a projector operating exactly at synchronous speed. This is usually accomplished by coupling the shutter shaft of the projector by a flexible shaft to a suitably geared synchronous motor. It is immaterial whether or not this motor actually furnishes the power to drive the projector so long as it is large enough to control the speed. When the picture is projected at synchronous speed, the announcer, if he rehearses a sufficient number of times, can readily give a performance that requires little or no editing to match it to the picture.

With improved quality in 16-mm recording, it was inevitable that there should arise a demand for re-recording equipment. The film

phonograph shown in Fig. 16 was developed by the Berndt-Maurer Corp. to meet this need. The machine uses essentially the same film-driving mechanism as the recorder, with minor modifications to make it suitable for the different shrinkage range encountered when running prints instead of raw-film stock. The optical system used to scan the sound-track delivers a light-beam 0.0005 inch wide. This makes the scanning loss at a given frequency almost exactly the same

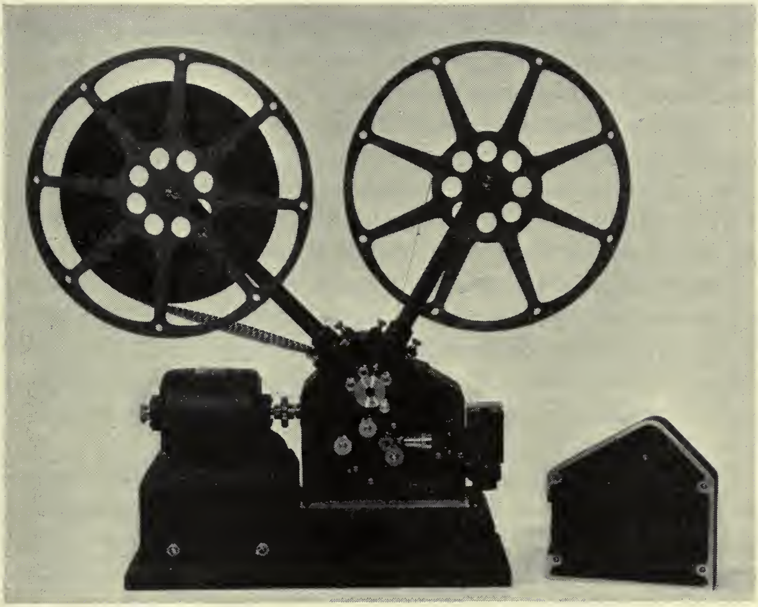

FIG. 16. Berndt-Maurer film phonograph, for rerecording from 16-mm sound-tracks.

as the loss in standard 35-mm reproducing equipment. The steadiness of film motion is such that re-recorded music betrays no audible speed variations. At least one active 16-mm producer is at present re-recording the sound for his entire product, using two of these machines to carry edited speech and background music (or sound effect) tracks.

The use of 16-mm Kodachrome for industrial motion pictures has assumed such importance during the past year that the topic deserves separate treatment in order that all the important facts may be assembled together.

Kodachrome picture duplicates are printed on Type *A* Kodachrome, using an assembly of special light-filters in combination with a light-source of accurately controlled color-temperature. These films receive a special type of processing which results in a different overall contrast and a different color balance from that obtained in the standard processing used for original camera exposures. The colors of the original film are reproduced to an excellent approximation.

In work on Kodachrome duplication at the Precision Film Laboratories it has been found possible to a considerable extent to correct variations of density among different scenes in an original film, and in many cases to correct overall departures from proper color balance. Nevertheless it should be stated emphatically that the best way to be sure of obtaining a good Kodachrome print is to make sure that all scenes included in the original edited film are correctly exposed and photographed under light of normal color balance.

Sound-tracks for printing on Kodachrome are either printed to obtain good-quality positive prints or are recorded as "direct positives" on the yellow-dyed Agfa recording stock (Type *250*). This stock is uniquely suitable for the recording of direct positives because it is capable of yielding an image of high density with very little "envelope" distortion.

Kodachrome itself appears to introduce relatively little distortion; therefore the positive sound-track used for printing should be one that reproduces well on a projector or film phonograph. It should be of density 1.3 or higher for best results.

When Kodachrome duplication was a new process the sound quality obtained was extremely disappointing, being low in volume and high in background noise. These defects have been overcome by a process which permits leaving a silver image in the sound-track edge of the film in addition to the dye image. Sound-tracks produced in this way are only eight to ten decibels lower in level than good black-and-white sound-tracks, and are low in background noise. There is a definite loss of high-frequency response, but this is not great enough to be objectionable when the original sound-track is of good quality.

Optical printing can be done with Kodachrome, but the tendency for slight surface irregularities on the original to appear as blemishes in the print (because of their effect in scattering light) is such that this method of printing should generally be avoided.

In general conclusion it may fairly be said that the equipment,

materials, and services that are available to the direct 16-mm producer today enable him to turn out a result at least as good from a technical standpoint as the results that have been obtained in the past by optical reduction from 35-mm negatives. The usefulness of direct 16-mm production lies in the fact that it makes this quality available at greatly reduced cost, thereby making it possible for business and education to employ motion pictures on an extended scale which has long been recognized as desirable, but which by previous methods has been found too costly to be practical.

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ADVANCEMENT IN PROJECTION PRACTICE*

F. H. RICHARDSON**

Summary.—*A brief review of projection practice from the beginning, pointing out the extremely poor conditions confronting projectionists in early days. Early projection equipments are illustrated and contrasted with those in use today. The work of some of the outstanding pioneers who had to do with early invention and improvements in projection equipment is described.*

It has been suggested that I prepare for presentation at this gathering, as a part of the projection session, an outline of the advancement made in presentation of the finished product of our industry to its purchaser, the public—in other words, in projection and its practices from the earliest days until now.

The task of preparing this paper was undertaken without consideration of the wide research required to obtain and verify all the data that would be necessary to make such a record complete. Moreover, if anything like a complete record were required, the presentation would consume far more time than a meeting such as this could possibly afford.

An attempt has been made therefore to supply only a few of the highlights of the advances made in projection, and some of the dates provided should be regarded as only closely approximate. Furthermore, it should be understood that this record has to do only with projection in the United States. Space limitations prevent consideration of the notable pioneer work of many projectionists and equipment manufacturers in Europe, or the splendid accomplishments of pioneers in allied fields, such as, for example, Louis Lumière, in France; Robert Paul, in England; Oskar Messter, in Germany; or of W. K. L. Dickson, who assisted Thomas A. Edison in the vast amount of research that finally produced a practicable motion picture camera, as well as many others who assisted in bringing our great

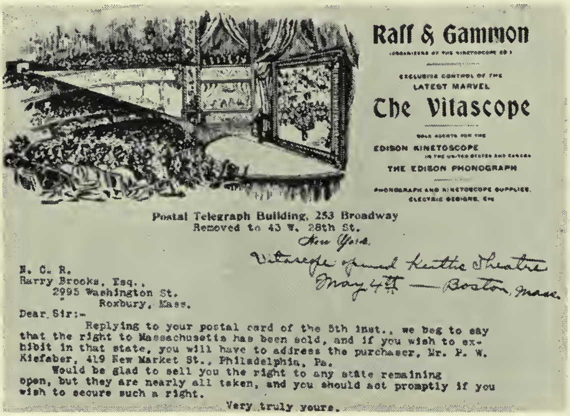
* Presented at the 1940 Spring Meeting at Atlantic City, N. J.; received May 1, 1940.

** Quigley Publishing Co., New York, N. Y.

industry into existence and building it into the splendid thing it is today.

But when we attempt to look back through the mists that shroud the years as soon as they pass into history, growing denser from year to year, we find many details hidden wholly from view, and others are seen but indistinctly, which emphasizes the importance of making authentic records of outstanding events at the time of their occurrence.

Those of us remaining who still have some first-hand knowledge of the introduction of the motion picture into the theatrical field feel amazed at the rapid advancement and vast improvement achieved



Raff & Gammon

EXCLUSIVE CONTROL OF THE
LATEST MARVEL

The Vitascope

EDISON KINETOSCOPE
THE EDISON PHONOGRAPH
PHONOGRAPH AND KINETOSCOPE SUPPLIES,

Postal Telegraph Building, 253 Broadway
Removed to 43 W. 28th St.
New York.

Vitascope opened Keiths Theatre
May 4th — Boston, Mass.

S. C. R.
Harry Brooks, Esq.,
2995 Washington St.
Roxbury, Mass.

Dear Sir:-

Replying to your postal card of the 5th inst., we beg to say that the right to Massachusetts has been sold, and if you wish to exhibit in that state, you will have to address the purchaser, Mr. F. W. Kiefaber, 419 New Market St., Philadelphia, Pa.

Would be glad to sell you the right to any state remaining open, but they are nearly all taken, and you should act promptly if you wish to secure such a right.

Very truly yours.

FIG. 1. Original letterhead of Raff & Gammon featuring the "Vitascope".

in the presentation of life-size motion pictures to theater audiences since its first successful introduction in the United States at Koster & Bial's Music Hall on 34th Street, West of Broadway in New York on the evening of April 23, 1896. The projector used that day was a so-called Edison Vitascope, which upon that occasion was in charge of Mr. Thomas Armat who had built and designed it himself. It had what is known as a "beater" intermittent movement. This projector had been previously used to give a demonstration to Messrs. Raff and Gammon in the Postal Telegraph Building, 253 Broadway, New York. This firm was managing the exhibitions of the Edison peephole projector, then used considerably for showing miniature motion pictures. The name "Vitascope" was given the projector by Mr. Armat. Its patent number is 673,992.

Subsequently Mr. Armat developed and patented another projector mechanism in which was incorporated the star or Geneva-cross intermittent movement which is now, in greatly refined form, in use in motion picture projectors throughout the world. This mechanism was covered by U. S. Patent No. 578,185, filed and published March 2, 1897.

Armat therefore was not only the inventor of the first satisfactory intermittent movement, as applies to motion picture projectors, but

FIG. 2. The first "motion picture theater," New Orleans, La.; *second from left,* William Reed, projectionist; *fourth and fifth from left,* William Rock and Walter Wainwright, proprietors.

was the first to project motion pictures successfully before a theater audience in this country. He is of right entitled to be hailed as father of the motion picture projector as we know it today. Although the years have added very many refinements, the basic principles of the projector have not been altered. Mr. Armat still lives, in the city of Washington, D. C.

The events leading to the production of a really practicable motion picture projector are, so far as ascertainable, as follows: First, a showing of motion pictures, approximately life size, was staged by Armat and C. Francis Jenkins, founder of our Society, at the Cotton States Exposition, Atlanta, Ga., 1895. The projector, however,

lacked a framing device. It had no provision for the loops, so necessary for successful projection. It had an intermittent movement that was found to be impracticable for commercial use.

Later Armat remodeled the mechanism, retaining the beater movement but adding provision for forming the loops. This was the mechanism used for demonstration before Messrs. Raff and Gammon in 1896, and afterward used at Koster & Bial's Music Hall, where its performance was loudly cheered by the audience.

Still later, not satisfied with the beater type of intermittent movement, Armat modified the Geneva-cross movement, long used for other purposes, to essentially its present form, and installed it in his Vitascope. Armat's Vitascope intermittent employed one cam-actuating pin. Later Edison, for some inexplicable reason, added a second pin to the driving cam, but, later still, finding it very inefficient as compared with the one-pin movement, he withdrew it and returned to the original Armat one-pin movement. So far as I can recollect or ascertain, no other projector manufacturer adopted the two-pin movement. The one-pin movement enabled the use of a three-bladed rotating shutter, which with the relatively low projection speed (60 feet of film per minute) then in use was necessary to eliminate flicker. It gave the film a smooth, gradual accelerated start-and-stop movement and worked wonders in the reduction of stresses at the film sprocket-holes and of eye-straining flicker by enabling the use of either a two- or three-bladed shutter.

After witnessing a demonstration of Armat's projector, Edison agreed to manufacture it. However, Edison was convinced, as was almost everyone else at the time, that the motion picture was merely a novelty and would die out as soon as it ceased being a novelty. First production was limited to fifty projectors, instead of the eighty demanded by Raff and Gammon. The projector was called the "Edison Vitascope" because Messrs. Raff and Gammon believed that Edison's name would have commercial value, and also because the Edison Company was to furnish the necessary films, and Edison held patents or applications for patents controlling both the films and the camera for making the picture.

No satisfactory means was provided on the first projectors for framing the picture. Later, Albert E. Smith, one of the partners in the Vitagraph Company, while experimenting with a frictional feed projector with (it is believed) an idea of avoiding the Edison perforated film patent, developed the framing device essentially as

we now know it. He patented it as U. S. Patent No. 673,329, dated April 30, 1901. Prior to this, framing was accomplished by means of a picture-size, sliding frame, which was all right in a way but threw the picture off the optical axis and was otherwise not so satisfactory as the Smith device.

Fig. 1 shows a letter written by Messrs. Raff and Gammon. For reasons already explained the projector went forth as the "Edison Vitascope" and was introduced on a state rights basis. This letter

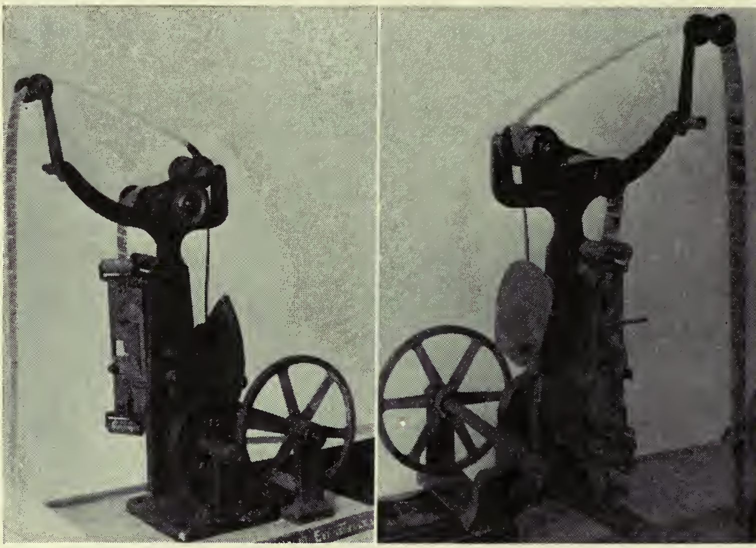


FIG. 3. Side views of one of the first projectors.

shows plainly the avidity with which the state rights were snapped up.

Let us now turn to things directly connected with projection, disregarding sound as being too new to be regarded in any way as historic.

As already stated, the first showing of life-size motion pictures in acceptable form in a theater occurred at Koster and Bial's Music Hall on May 23, 1896. The first theater to open its doors as a purely motion picture theater—at least the first of which any authentic record can be found—began business in midsummer at 623 Canal Street, New Orleans, La. Fig. 2 is a photograph of the "theater."

Its owners, William Rock and Walter Wainright, stand at the right. Mr. Rock was later one of the partners in the Vitagraph Company, one of our early-day film producers.

The little theater was an ordinary store room, equipped with an unbordered cloth screen and ordinary wooden kitchen chairs. The projector was on a raised platform, surrounded by a cloth curtain. Mr. William Reed, who is with us today and who has been continuously projecting motion pictures since that time, was the "operator."

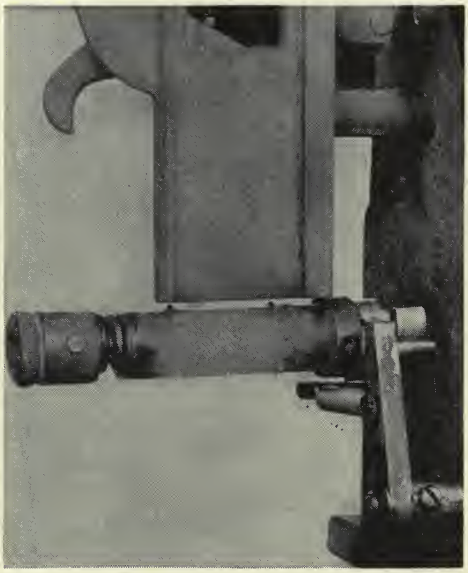


FIG. 4. Intermittent sprocket of the projector shown in Fig. 3.

Looking back we can not but feel justifiable pride in the fact that from an extremely lowly beginning projection has advanced to a plane of excellence commanding attention and respect from all. Not only have the results presented to the theater audiences advanced wonderfully in point of excellence, but the "operator," who in the beginning represented perhaps the least respected item in all the industry's personnel, has himself advanced to a plane where those who respect themselves and the work in which they are engaged are well considered and treated with respect. No longer are they looked upon as merely operators of a machine. Instead they are accorded the

respect due to men possessed of the wide range of ability and knowledge requisite to competent handling of the intricate, finely adjusted modern projection installation. He is no longer known as "operator," but as "projectionist."

In the beginning the "machine operator" knew almost nothing about projection and its problems; in fact, he did not conceive of

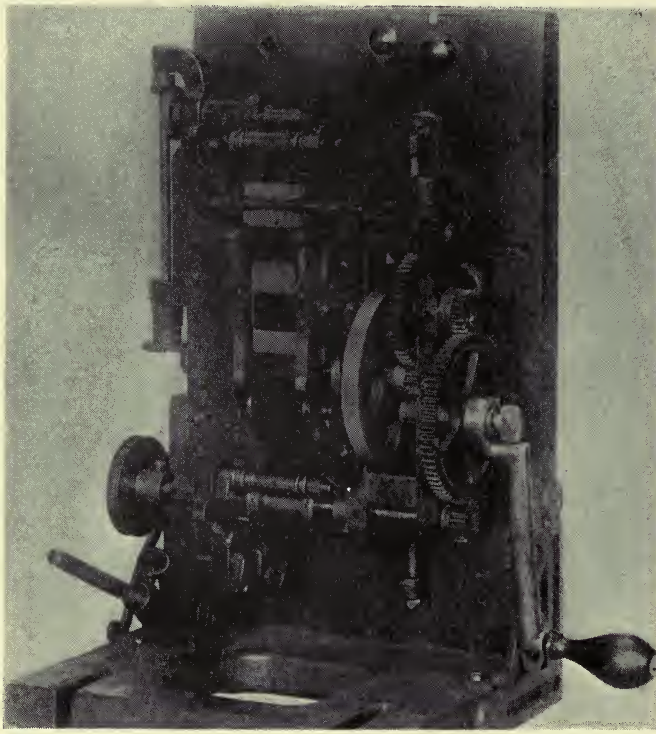


FIG. 5. Powers No. 3 projector.

projection as having any problems. Anyone who knew how to make a crude film splice, trim a lamp, thread a film into the projector, and do the rewinding, was regarded as equipped with all the knowledge required.

Everything with which he was provided to do the work was almost primitive in design and crude in construction, and the film was poor, of uneven thickness and unevenly perforated.

Illustrative of the primitive equipment is the machine shown in Fig. 3, a very early mechanism made by A. A. Heldt, of Evansville, Indiana. Fig. 4 is a close-up of the intermittent sprocket.

Fig. 5 shows the first model of the celebrated Powers projector, put forward under the trade name "Powers Peerlescope." It was made in 1902 by Nicholas Power, in a tiny shop located on Nassau Street, in New York City. This projector was equipped with a gas-light source, and was belt-driven, directly from the rim of the crank-wheel.. It had tiny, telescoping legs and a cloth bag, into which the

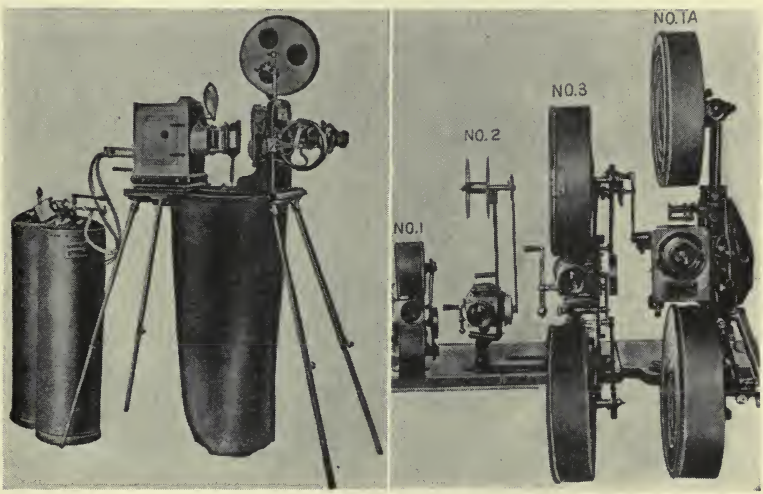


FIG. 6. (*Left*) Early Edison projector equipped for gas; (*right*) Nos. 1, 2, and 3, Optigraph; No. 1A, Motiograph.

film dropped after having passed through the mechanism. In the later models some city authorities banned the cloth bag, demanding its replacement by a sheet-metal tank or box some three feet high. The projector lamp house and mechanism were attached to a wooden board, usually of black walnut, which then was attached to the top of the tank, the supporting legs being omitted.

The film entered the tank through a rectangular opening under the mechanism. This opening was fitted with a sliding metal cover, held in the open position against a coiled spring, into the holding wire of which a fuse link was connected. Into these tanks as many as three 1000-foot reels of film were often run in a loose heap. In

most cases there was but one projector in each theater. Theater owners, at least in the Middle West, had insufficient confidence in the motion picture as a form of amusement to risk the expense of installing a second projector. Audiences therefore had to sit in darkness at the end of each reel while another reel was threaded up, the lamp trimmed, *etc.* Great haste on the part of the projectionist was, of course, demanded. Usually he would remove a carbon stub and lay it on top of the tank, whence it could roll through the open-

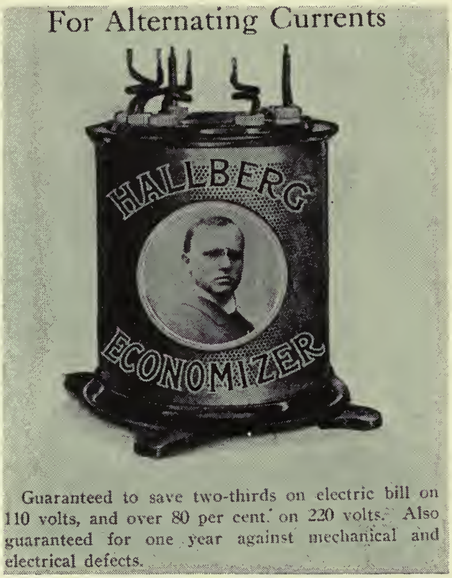


FIG. 7. The Hallberg "Economizer."

ing and drop into the pile of loose film; and if it were hot a fire would occasionally result. In case of a fire the fuse would melt and the cover of the opening would snap shut. Since there was no other opening save a door in the side held shut by a substantial metal latch, and since the mass of burning film generated great quantities of gas, either the door would blow off or the tank would blow up. That is where newspapers acquired the idea that film was explosive.

The tail end of each reel was left hanging out of the opening to be retrieved for rewinding. If, as sometimes happened, it slipped into the tank, the "operator," who had to rewind in the limited time between shows, was faced with a very real trouble. However, it

was rather astonishing to see how smoothly a 1000-foot length of film would pull out of a 3000-foot loose pile, at high speed, with but rare inclination to tangle.

There were two things over which projectionists of earlier days had no control that made even passable excellence in results wholly impossible. They were, first, a combination of inaccuracy of film perforation and, second, a great lack of mechanical accuracy in projector mechanisms, particularly the intermittent sprocket and intermittent movement. The condition in this respect was so bad up to about 1910 that the screen image was seldom steady during the projection of three consecutive feet of film.

The engineers of the projector-manufacturing companies deserve the highest credit for the improvements they have accomplished during the ensuing years. Today we often view a production critically scarcely being able to detect the slightest movement of the screen image as a whole. Other credit must go also to the carbon manufacturers. In the beginning we had nothing but ordinary carbons such as were used for street-lighting arc lamps. They were chock full of various impurities; they were not accurately straight; they were filled with hard and soft spots and cracks. The screen illumination was unsteady, variable in tone, and likely to fail entirely without an instant of warning.

About 1910 the demand for carbons for projection became so great and the demand for improvement so insistent that a continuous line of development immediately followed. Today we have a light-source that is extremely steady, and a screen illumination of dazzling whiteness.

The lens manufacturers also have contributed to the development, with faster lenses of wider aperture, and most recently, the new coated lenses for inhibiting surface reflections. Sharp, clear images magnified from an area of less than one square-inch to as much as 18×24 feet are usual today.

To illustrate the strides that have been made, Fig. 6 shows projectors such as were used in early days. Barring a few wires and one or two switches this picture shows everything that most projection installations included, except possibly a stereopticon, even as late as 1907. The machine on the left is an Edison machine equipped for gas. Note the thin, weak, adjustable legs and the small lamp house. At the right are Motiograph models of approximately the same date: Nos. *1*, *2*, *3*, and *1A*, early examples of

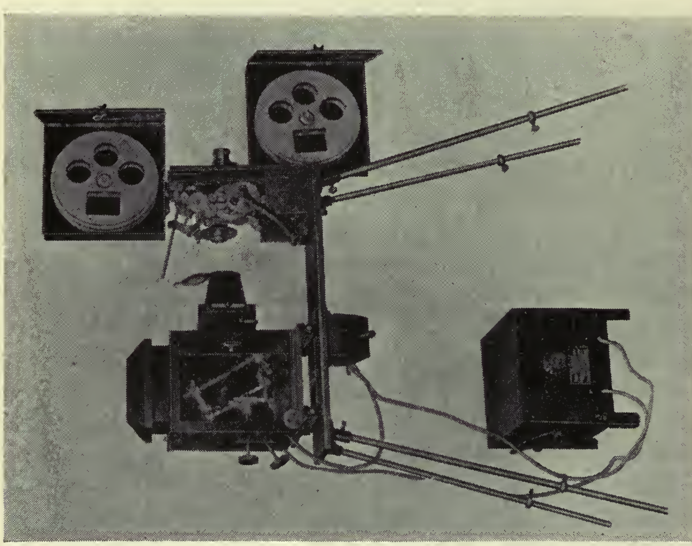


FIG. 8. The Edison exhibition model.

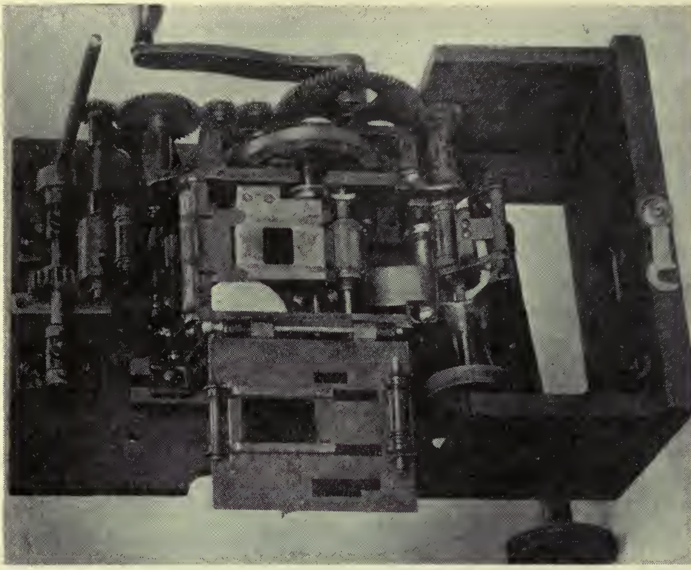


FIG. 9. The Edison exhibition model. It and the Powers projector dominated the field until about 1910.

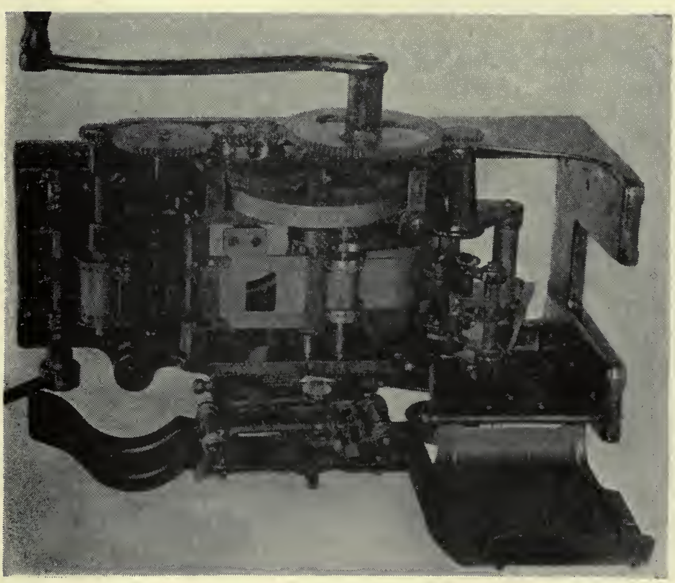


FIG. 10. Edison Type *B*, metal-frame projector. This followed the Exhibition model (Fig. 9), and was the last Edison placed on the market. Later Edison built a more elaborate projector, but it was never marketed.

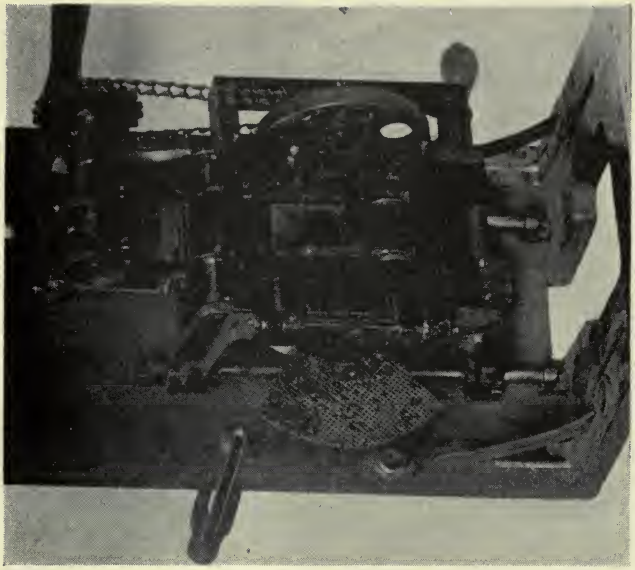


FIG. 11. Powers No. 1 projector mechanism. Note the perforated inside shutter blade; also the wooden frame upon which the mechanism was mounted. The upper reel holder (not shown) mounted at the top of the wooden frame served also as rewinder. The upper sprocket was chain driven. The handle projecting toward the right near the top of the photo was the framer.

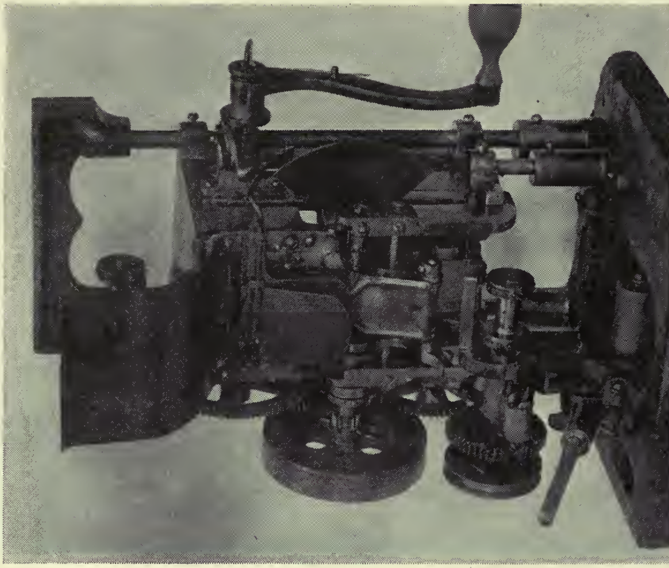


FIG. 13. Powers No. 4 projector.

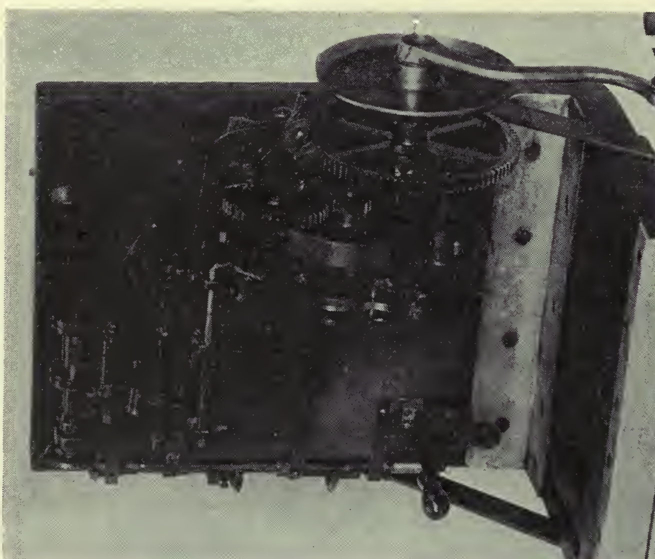


FIG. 12. Powers No. 2 projector.

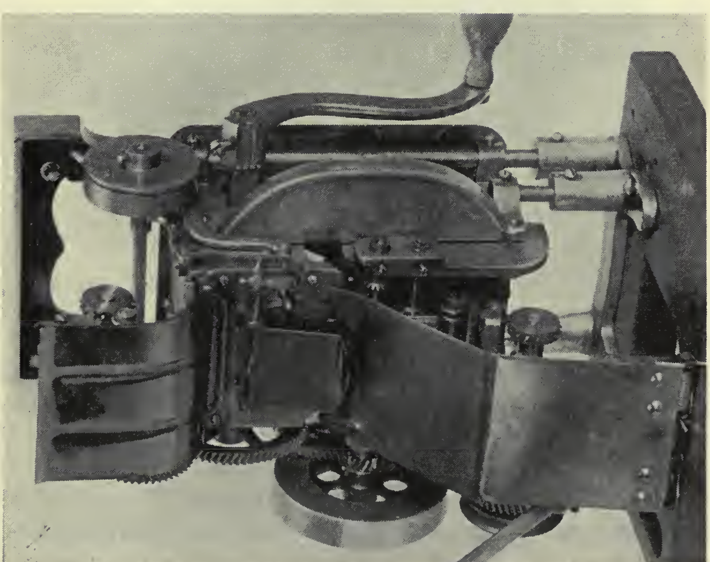


FIG. 14. Powers No. 5 projector.

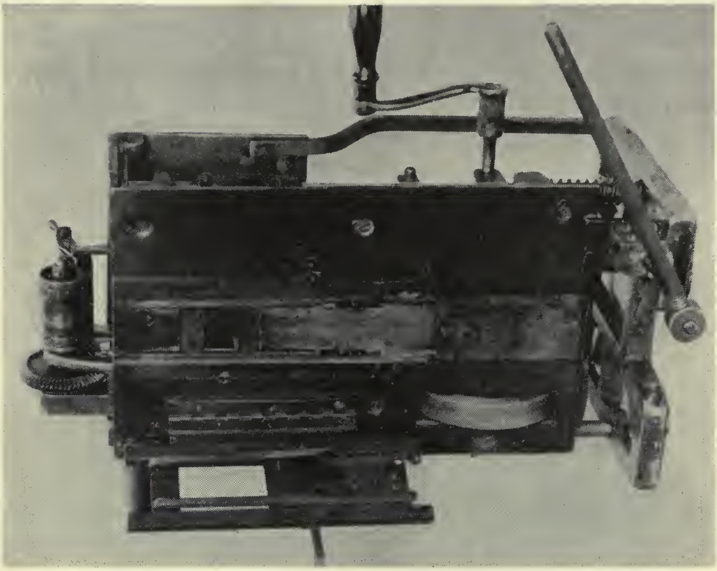


FIG. 15. Pink's Vanascope; quite popular in and around Chicago about 1905–10; claw movement type.

high-accuracy projector construction. Another projector of this period, called the Kinedrome, was put out by a Chicago company. It was not placed on sale, but was rented to theaters, together with an operator and a supply of film.

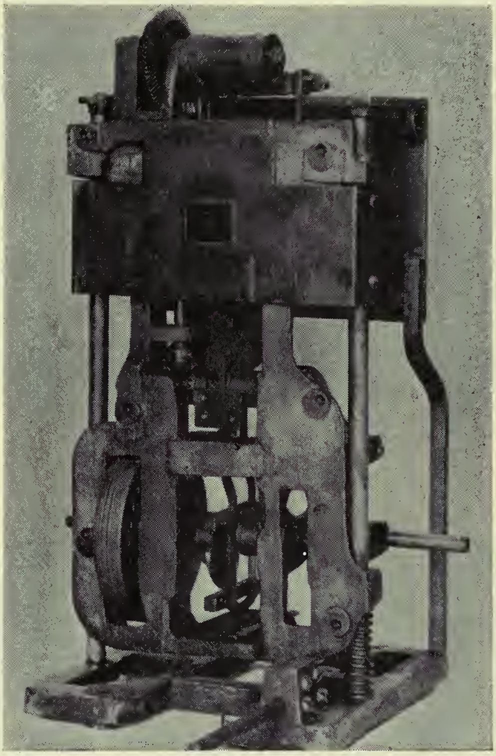


FIG. 16. The Viascope, marketed to a limited extent by the Vitagraph Corp. about 1908–10.

Up to about 1909 the alternating current for motion picture projection light-sources had been controlled wholly by rheostats, which not only wasted power but were difficult to handle. In that year, J. H. Hallberg, a New York City supply dealer, produced the "Hallberg Economizer" (Fig. 7), a low-voltage transformer. Alteration of its connections made it capable of supplying three different values of current to the arc, at the same voltage. It immediately became very popular, and hundreds of them were placed in the theaters.

This transformer was the first step forward in an improved alternating-current light-source.

It has been found impossible to obtain photographs of the very early Edison kinetoscope. However, through the courtesy of the Historical Research Organization of Thomas A. Edison, Inc., Figs. 8 and 9 were obtained. These show the "Exhibition Model," re-

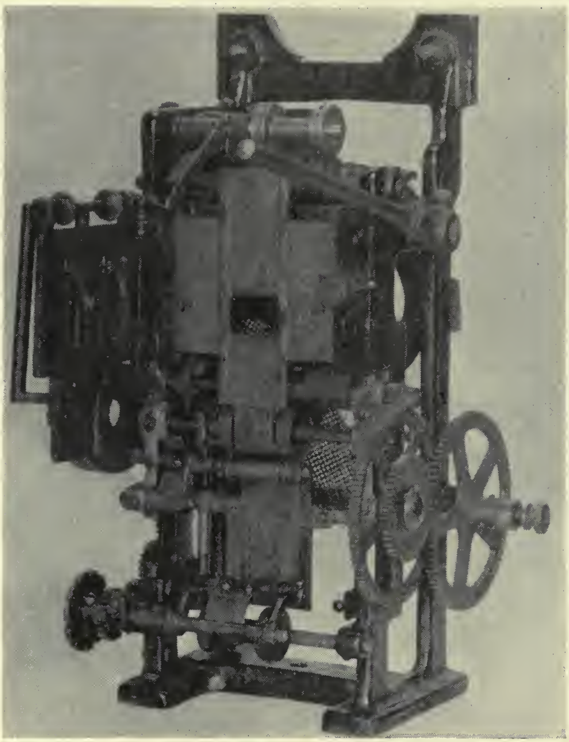


FIG. 17. Lubin Cineograph; discontinued about 1910.

leased in 1898 and kept on the market until Mr. Edison's final retirement from the projector manufacturing field about 1914.

Fig. 10 shows the Edison Type *B* mechanism. The exact date on which this was placed on the market is not certain, although it must have been about 1909. It had a metallic supporting frame and several other minor improvements as compared with the Exhibition Model. Each of these models served a wide field and gave what was regarded as good service in that day.

About 1914 Edison developed a model that was marketed under the trade-name Edison Super-Kinetiscope. However, upon its theater try-out some rather serious faults developed. Also about this time a bad fire occurred at the Edison plant, and many jigs, dies, *etc.*, necessary to the manufacture of projectors were destroyed. Mr. Edison was then engrossed in his notable storage battery research, and sold his complete projector manufacturing interest to

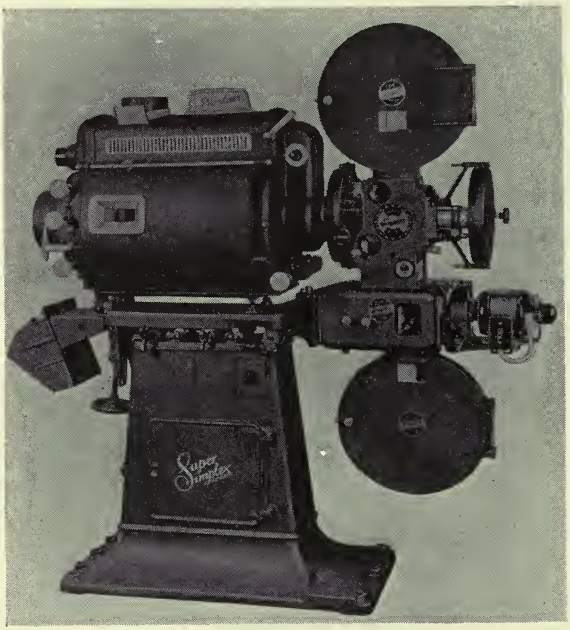


Fig. 18. A modern projector, by way of contrast.

the Baird Machine Company, which at that time was growing rapidly in the projector manufacturing field, but later discontinued upon the death of its founder, Mr. Baird (about 1914).

Figs. 11 to 17 show a number of other early projector mechanisms.

One important development must not be overlooked. In 1909 Nicholas Power started experimenting on a wholly new type of intermittent movement, which finally appeared in the Powers Six mechanism, released to the trade early in 1911. This movement was withdrawn after the consolidation of the Powers Company and the Precision Machine Company, the latter being the manufacturers

of the Simplex projector. However, the Powers movement was acclaimed by projectionists as the best movement ever delivered to them.

In Fig. 18 is shown a modern projector, showing the contrast between the old machines and the splendid equipment we now have.

Some of the outstanding pioneers in the American field of projection should be named before closing: Thomas Armat, who in 1895 made life-size motion pictures possible by introducing into the projector mechanism the Geneva cross; Thomas A. Edison, who took over the manufacture of the Armat inventions and put them on the market; Nicholas Power, who accomplished a great work in improving the projector; A. C. Roebuck, who demonstrated the improvement in results that could be achieved by accurate mechanical construction of projector mechanisms; Frank Cannock and E. S. Porter, the former notable for his constructive work in improving the projector, the latter for making Mr. Cannock's work possible by financial backing as well as for advancing many ideas himself. It was these men who paved the way toward the modern projector.

One important feature of the projector development should not be overlooked: namely, the substitution of the outside for the inside shutter, later removed from in front of the projection lens and placed between the light-source and the aperture, where it functioned equally well from the optical viewpoint and reduced the heat at the aperture by fifty per cent. Finally came the combination front and rear shutter, which reduced the time of occultation of the light-beam and added considerably to the amount of light delivered to the screen. Next in importance perhaps was the substitution of a solid, rigid supporting base for the entire projector. One might continue indefinitely to itemize the improvements that have occurred in projection, but as the finishing touch we have, of course, addition of sound to the picture about 1929, and the consequent great elaboration of the projection equipment.

THE ELIMINATION OF HYPO FROM PHOTOGRAPHIC IMAGES *

J. I. CRABTREE, G. T. EATON, AND L. E. MUEHLER**

Summary.—*It is very difficult, if not impossible, to remove the last traces of hypo from photographic papers by any known procedure of washing. The sulfur in the residual hypo ultimately, and especially under abnormal conditions of temperature and humidity, combines with the silver image to form yellowish-brown silver sulfide. This phenomenon is known as sulfiding or "fading" of the image. The various factors which affect the rate of fading of images and the washing out of hypo from films and papers are outlined.*

Chemical methods of hypo elimination have been proposed from time to time but the majority of these have not been satisfactory because they tend to leave substances such as thionates in the photographic material, which are equally as difficult to wash out as hypo and which also tend to sulfide or fade the silver image. A new hypo eliminator is recommended consisting of two volatile chemicals, hydrogen peroxide and ammonia. This eliminator oxidizes the hypo to sodium sulfate, which is inert and soluble in water, while any excess eliminator evaporates on drying.

Two formulas and treatments are proposed: (1) Complete elimination of hypo for use by the professional, advanced amateur, and photofinisher who demand the highest standard of photographic quality in their prints. (2) Almost complete elimination of hypo (less than 0.01 milligram per square inch). Since the conditions to which prints will be subjected are rarely known in advance, use of the "complete elimination treatment" is advised in all cases.

In the processing of photographic developing-out materials such as gelatin silver emulsions coated on paper, film, or glass supports, if after fixation, the hypo (sodium or ammonium thiosulfate) is not completely eliminated from the processed material by washing or other means, under suitable conditions of temperature and humidity during storage, the silver image will tend to "fade."

This fading is a result of the conversion of more or less of the silver image to silver sulfide by the sulfur present in the residual hypo, and is manifest by a change in hue of the image first to yellowish

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* Communication No. *780* from the Kodak Research Laboratories. Presented at the October, 1940, meeting of the Photographic Society of America, at Cleveland, Ohio (*J. Phot. Soc. Amer.*, **VI** (October 25, 1940)), p. 6.

** Eastman Kodak Co., Rochester, N. Y.

brown, then to yellow and, in most cases, the change is accompanied by a yellowing of the unexposed portions of the image. This yellowing of the highlights is a result either of (*a*) the use of an exhausted fixing bath, or (*b*) insufficient fixation whereby complex silver-sodium thiosulfates are retained and, under the proper conditions, decompose to give yellow silver sulfide.

In addition to attack of the silver image by hypo within the gelatin layer, many external agents are also effective, the most significant being hydrogen sulfide which is present in coal gas (illuminating gas). High humidity and temperature accelerate this reaction tremendously. Sulfur dioxide and other acid gases, in the absence of hypo, affect the silver image to a much less degree than hydrogen sulfide.

The rate at which a silver image fades depends upon many factors, including (*1*) the concentration of hypo (or tetrathionate) in the image layer, (*2*) the concentration of hydrogen sulfide and other acid gases in the atmosphere, (*3*) the grain size of the silver image, and (*4*) the temperature and humidity of storage.

Tests have shown that the degree of fading in a given time is roughly proportional to the concentration of hypo up to a certain limit, and a concentration as low as 0.005 milligram per square-inch may cause fading with fine-grained images, especially in the case of papers.

An increase in the humidity, temperature, or both accelerates the rate of fading, and a combination of high humidity and high temperature, which conditions usually exist in tropical countries, is fatal to a photographic print containing hypo.

The presence of saline matter and acidic gases in the atmosphere also tends to increase the rate of fading.

Since fading or sulfiding of the image must necessarily take place initially at the surface of the image grains, fine-grained emulsions will tend to fade much more rapidly than coarser-grained emulsions and, in practice, chloride paper emulsions give images which are much more susceptible to fading than bromide emulsions. Similarly, a fine-grained positive transparency is much more susceptible to fading than an image on a high-speed negative emulsion.

Sodium thiosulfate tends to oxidize when exposed to the air with the formation of thionates and some sulfate. Certain recommended hypo eliminators oxidize hypo to sodium tetrathionate but the presence of this compound (and probably other thionates) is harmful

because tetrathionate causes sulfiding of silver images almost as readily as hypo.

During this investigation it was essential to use an accelerated fading test in order to obtain directly comparable results within a reasonable time. Crabtree and Ross[1] have recommended the storage of test strips in a sealed glass container over water stored at a temperature of approximately 110°F. In the present investigation

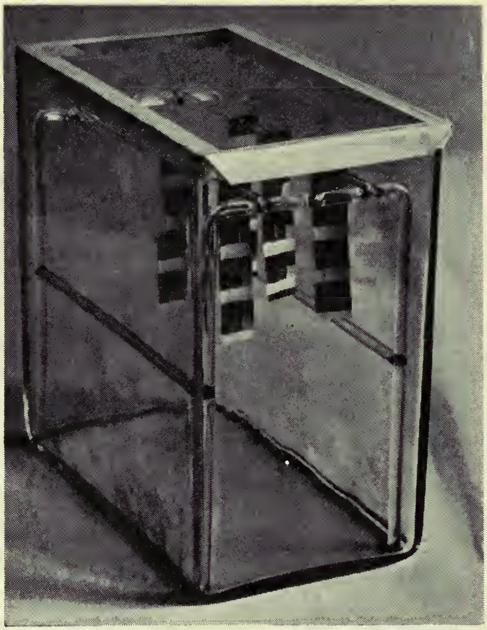

FIG. 1. Apparatus for accelerated fading tests.

these storage conditions were maintained, the strips (negatives and prints) being suspended on glass rods in sealed glass containers, as shown in Fig. 1.

THE ESTIMATION OF HYPO IN PHOTOGRAPHIC MATERIALS

A fallacy of the majority of investigations on hypo elimination has been the attempted estimation of the residual hypo by measurement of the hypo contained in the wash water. Testing solutions usually employed for this purpose are alkaline permanganate, iodine-azide, and mercuric chloride. These methods give a fairly accurate meas-

ure of the effect of washing upon "readily diffusible hypo" but they give no indication of the quantity of hypo retained by the photographic material.

In the case of images on glass or film, the hypo is usually removed quite readily by washing but, in the case of paper prints, it is extremely difficult, if not impossible, to remove all traces of hypo by washing alone. Apparently the thiosulfate ion is tenaciously held by the paper fibers and the baryta coating. A quantitative determination of the residual hypo in the photographic materials themselves is therefore necessary.

In 1908, Lumière and Seyewetz[2] recommended the use of silver nitrate as a spot test on prints and, again in 1935, Weyde[3] suggested the treatment of prints with silver nitrate to determine the hypo concentration but no details of a quantitative standardization were given.

In the present investigation, the silver nitrate test was standardized in such a manner that the transmission density of a print bathed in silver nitrate was proportional to the quantity of hypo contained in the print and quantities as low as 0.005 milligram of hypo per square inch were determined successfully. The data obtained were also confirmed by a quantitative determination of the reducible sulfur in the paper.[4] With this method as a tool, a much more direct comparison of the effectiveness of many suggested "hypo eliminators" was possible.

With the usual permanganate test which consists in allowing the surplus water from a washed single-weight print to drain into a solution of potassium permanganate, a zero test is obtained when the silver nitrate test indicates the presence of about 0.2 milligram of hypo per square inch, a quantity which is capable of producing an objectionable degree of fading.

To determine the hypo in film, the mercuric chloride-potassium bromide test recommended by Crabtree and Ross[5] was used. A square-inch of the material is placed in 10 cubic-centimeters of the reagent and, after 15 minutes, the turbidity is compared with the turbidity produced in a series of standard solutions. This test accurately measures quantities of hypo in films as low as 0.005 milligram per square-inch.

The mercuric chloride reagent was applied to prints but found incapable of reacting with all of the hypo in the sample. Since only the hypo which diffuses out of the film or print contributes to the

opalescence, the test measures only the "readily diffusible" hypo, whereas in the silver nitrate test, the silver nitrate reacts with all of the hypo within the film or print. Comparison of the results obtained with the mercuric chloride and the standardized silver nitrate test with prints is given in Table I.

TABLE I

Comparison of Mercuric Chloride and Silver Nitrate Test with Photographic Prints

Washed Prints (Minutes)		Hypo Content (Mg per Sq In)	
Single-Weight	Double-Weight	Mercuric Chloride	Silver Nitrate
15		0.004	0.073
30		0.01	0.042
60		Trace	0.020
	15	0.02	>0.320
	30	0.01	0.173
	60	Trace	0.134

THE ELIMINATION OF HYPO BY WASHING

The washing of photographic materials has always been accepted as a necessary operation but the importance of removing the last traces of hypo has often been underestimated.

Negatives.—For washing it is always preferable to use running water in a system such that an "ideal stream" prevails, that is, a sufficient volume of water passes over the surface of the material so that it removes the hypo from the surface of the emulsion faster than the hypo diffuses out. When washing in a tray in still water, the water must be changed often and the negatives agitated continually. Under ideal conditions of water renewal, the most important factors which affect the rate of washing of films are: (*1*) the temperature of the wash water, and (*2*) the composition of the fixing bath.

The curves in Fig. 2 illustrate the effect of the temperature of the wash water on the rate of elimination of hypo from Eastman Verichrome film. The films were washed under "ideal" conditions of water flow and it is seen that a change in temperature from 40° to 65°F increases the quantity of hypo removed in a given time of washing by about 33 per cent, whereas increasing the temperature from 65° to 80°F almost doubles the quantity of hypo removed. A temperature of 60° to 70°F is recommended in view of the danger of swelling and softening at higher temperatures.

The hypo was also more readily washed from film which had been fixed in a nonhardening fixing bath than from film fixed in a potassium alum fixing bath. The use of a chrome alum fixing bath resulted in washing times somewhat less than those for potassium alum-hardened negatives.

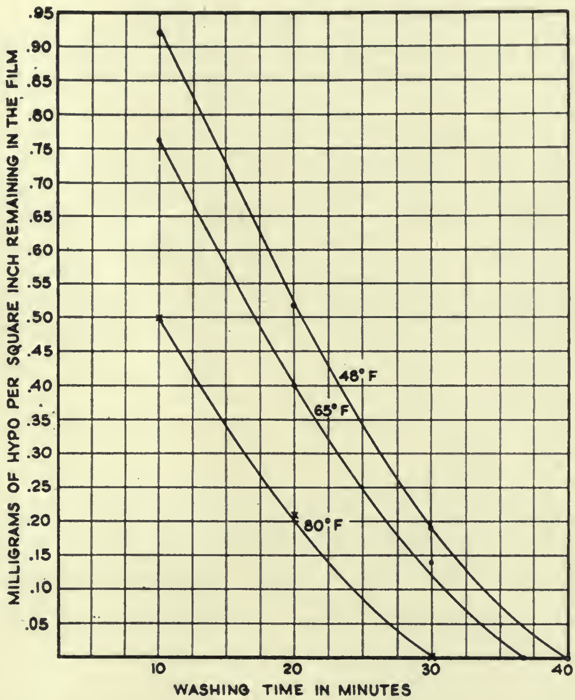

FIG. 2. Effect of wash water temperaure on rate of hypo elimination from Eastman Verichrome Film.

Prints.—Thorough washing is much more important in the case of prints than with negatives because fine-grained paper emulsions fade much more readily and, in some cases, in the presence of as small a quantity of hypo as 0.002 milligram per square-inch. Not only is the image more susceptible to fading but relatively high concentrations of hypo are usually retained in the print. This retention of hypo is due to the presence of the paper fibers and the baryta coating and, since, even with extremely long times of washing with an "ideal stream of pure water," traces of hypo are retained in prints

(especially with double-weight stock), it is apparent that the thiosulfate ion is probably mordanted or adsorbed to the fibers and baryta.

As in the case of negatives and assuming an "ideal stream" for washing, the two most important factors to be considered in the elimination of hypo from prints are: (*1*) the temperature of the wash water, and (*2*) the composition of the fixing bath.

In 1908, Lumière and Seyewetz[6] and in 1910, Hauberrisser[7] recommended the use of elevated temperatures during washing but,

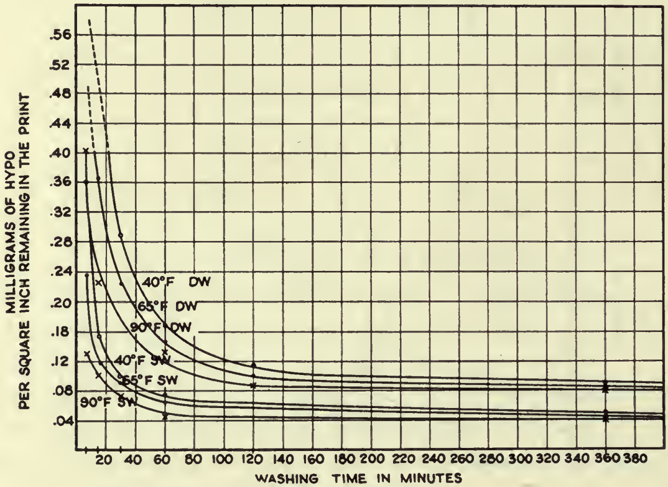

FIG. 3. Effect of temperature of wash water on rate of elimination of hypo from single and double-weight prints.

to date, no extensive practical application has been made of the suggestion. The curves in Fig. 3 show the effect of the temperature of the wash water on the rate of elimination of hypo from single and double-weight prints.

Single and double-weight papers were washed for 20 hours, but the curves indicate that a maximum elimination is approached after 1 or 2 hours. The very great effect of temperature of the wash water is evident for the shorter washing times but is not so great for the longer times of washing. Washing for as long as 20 hours did not eliminate the last traces of hypo in either single or double-weight papers. With extended washing, the rate of elimination tends to approach zero. The quantities of hypo retained after prolonged

washing are sufficient to cause fading under certain storage conditions. It is evident, therefore, that use of a hypo eliminator is a necessity if the highest degree of permanence is desired.

The prints shown in Fig. 4 were washed for times sufficient to leave the designated quantities of hypo in them and were then stored under

FIG. 4. Accelerated fading tests illustrating the relative fading produced by decreasing concentrations of hypo. (Hypo content in milligrams per square-inch—chloride emulsion.)

the accelerated fading conditions previously described. They illustrate the effect of increasing hypo concentration on the degree of sulfiding or fading of the image and emphasize the necessity for the complete elimination of hypo from papers coated with fine-grained chloride emulsions.

HYPO ELIMINATORS

The term "hypo eliminator" was first used by Hart[8] to indicate a solution which was capable of oxidation of thiosulfate to neutral sulfate. Oxidizing agents only were known as eliminators but the term acquired general use and is now applied to any solution or chemical that either oxidizes the hypo or assists in its elimination.

Many chemical treatments have been proposed to assist in the elimination of hypo or to make photographic prints permanent. Some of these may be listed as follows: alum (1855); hypochlorous acid (1864); hydrogen peroxide (1866); sodium hypochlorite (1866); ammonium carbonate (1866); iodine (1872); zinc hypochlorite (1881), known as Flandreau's eliminator; ammonium persulfate (1899); potassium percarbonate (1901); alkaline perborates (1903); potassium permanganate (1904); chloramine T (1922); alkali carbonate or phosphate (1923); dilute caustic soda (1925); peroxide and ammonia (1931); and 1 per cent sodium carbonate (1935).* None of the suggested treatments has been generally accepted nor has any stood the test of time. It has been shown that none of these recommended treatments, even when used following careful washing, was effective enough to eliminate the hypo completely. In several instances increased concentration of the constituents successfully oxidized the hypo but to the detriment of the silver image.

Two general types were found to be particularly effective, namely, (*a*) alkalies, and (*b*) oxidizing agents such as hydrogen peroxide-ammonia solutions.

Alkalies. Norton and Crabtree,** working with paper prints, recommended the use of dilute sodium carbonate solutions immediately after the fixation process and previous to washing. However, in view of the danger of precipitation of alumina with fixing baths containing alum, it is considered desirable to wash negatives or prints before the alkali treatment.

(*1*) *Negatives.*—Various alkalies were found to assist in the elimination of hypo from negatives but they were not equally effective. A quantity of film was normally processed and washed for 8 minutes at 65°F in running water, samples then being treated in distilled water, ammonium hydroxide, Kodalk, sodium hydroxide, and sodium carbonate solutions (0.3%) for 2 minutes. These samples

* A chronological bibliography is given in the appendix.

** Eastman Kodak Laboratories, July, 1923, unpublished results.

were washed for 2 minutes, dried, and analyzed by the mercuric chloride method which indicated the following hypo contents in milligrams per square-inch:

	Mg per Sq-In
Untreated	>0.06
Distilled water	0.02
Ammonium hydroxide (0.3%) *p*H = 10.40	Nil
Kodalk (0.3%) *p*H = 9.90	0.01
Kodalk (0.3%) *p*H adjusted to 10.40	0.005
Sodium hydroxide (0.3%) *p*H = 11.57	0.01
Sodium hydroxide (0.3%) *p*H adjusted to 10.40	0.01
Sodium carbonate (0.3%) *p*H = 10.48	0.005

Ammonium hydroxide was the most effective alkali and it also had the least effect on the physical properties of the emulsion. In most instances, regardless of the alkali, the time required to wash out the hypo completely was reduced by more than 50 per cent.

2. Prints.—An extensive study of the use of alkalies with respect to the elimination of hypo from prints indicated that ammonia was the most effective alkali. Sodium metasilicate, sodium hydroxide, and ammonia at concentrations of 0.08 Molar* caused the complete elimination of hypo from prints which had been washed in an "ideal" stream of water for 15 minutes at 65° to 70°F, but the hydroxide and metasilicate produced severe physical defects in the print. Ammonia could be effectively used at room temperature and did not damage the prints. However, the time of 45 minutes required for treatment was excessive.

Peroxide-Ammonia: (*1*) *Negatives.*—The use of hypo eliminators, other than alkalies, is not usually required in the processing of negative materials. However, the hydrogen peroxide-ammonia eliminator recommended below for prints is applicable to film emulsions also but must be used in lower concentrations (diluted 1:10) because of the tendency to soften and blister the emulsion.

(*2*) *Prints.*—The outstanding fault with the majority of oxidizing agents proposed for hypo elimination is their acid character or their need for an acid medium. An alkaline peroxide solution, on the other hand, is a very effective oxidizing agent for sodium thiosulfate and does not attack the silver image even in quite high concentrations.

* In grams per liter—sodium metasilicate (crystal) 17 grams; sodium hydroxide, 3.2 grams; ammonia (28%), 5 cubic-centimeters.

Hydrogen peroxide itself was recommended as early as 1866 by Smith[9] to be used in a dilution of 1:1000 for a minute or two. He later suggested that the acid in the peroxide be neutralized with soda. About the same time Spiller[10] reported an attempted use of a mixture of hydrogen peroxide with ammonia but declared that such a mixture was unsatisfactory because the two constituents "mutually decomposed." Subsequent workers reported that hydrogen peroxide itself did not oxidize all of the hypo to sulfate but produced some thionates. This is actually the case but alkaline peroxide having a suitable *p*H value oxidizes the thiosulfate completely to sulfate.

In 1931, a note in *Das Lichtbild*[11] mentioned the use of hydrogen peroxide as a hypo eliminator. Here, ammonia was added dropwise until the solution just smelled of ammonia, an adjustment which corresponds to that of Smith who used soda to neutralize the acid in the peroxide. It is evident, then, that the previous use of hydrogen peroxide was concerned with neutral hydrogen peroxide.

TABLE II

Change in pH with Increased Ammonia Concentration

Composition of Solution (Cc per Liter)			
H_2O_2 (3%)	Water	Ammonia (28%)	*p*H Glass Electrode
500	500		3.7
500	500	0.6 (*Das Lichtbild*)	9.0
500	500	2.0 (Marked odor)	9.3
500	500	10.0	9.8
250	750	10.0	9.95
125	875	10.0	10.15
	1000	10.0	10.75

Experiments in these Laboratories have shown that definitely alkaline peroxide solutions will oxidize sodium thiosulfate completely to sulfate and the study of alkalies in hypo elimination has shown that ammonia is the most suitable alkali for this purpose. It has the additional advantage that it is volatile, so that, after treatment, the only residue is a trace of sodium and ammonium sulfates. An investigation was therefore made of ammonia-peroxide solutions to determine their activity in the elimination of hypo from prints.

At the outset, mixtures of peroxide with increasing concentrations of ammonia were prepared to determine the *p*H range of the solution over which effective oxidation of hypo was attained (Table II).

Solutions having a pH value lower than 9.8 were not entirely satisfactory as hypo eliminators because of their low activity. The three solutions containing 500, 250, and 125 cubic-centimeters of 3 per cent peroxide per liter with 10 cubic-centimeters of 28 per cent ammonia in each were compared throughout the study. Dilutions with water of any of these solutions produced mixtures which would not efficiently remove the last traces of sodium thiosulfate. Table III illustrates typical results obtained by treatment in these solutions for different times after increasing times of washing.

TABLE III

The Elimination of Hypo from Double-Weight Prints with Peroxide-Ammonia

Peroxide-Ammonia (Cc per Liter)	Time of Washing (Min)	Time of Treatment (Min)	Hypo Concentration (Mg per Sq-In)
500 + 10	10	5	0.040
(Peroxide) (Ammonia)		10	0.006
3% 28%		15	Nil
	20	5	0.004
		10	Nil
	30	5	0.004
		10	Nil
250 + 10	10	5	0.038
(Peroxide) (Ammonia)		10	0.007
3% 28%		15	Nil
	20	5	0.008
		10	Nil
	30	5	0.007
		10	Nil
125 + 10	10	5	0.055
(Peroxide) (Ammonia)		10	0.007
3% 28%		15	Nil
	20	5	0.006
		10	Nil
	30	5	0.005
		10	Nil

It is apparent from Table III that, if double-weight prints are washed for 20 minutes and then bathed for 10 minutes in the eliminator solution, the hypo is completely eliminated from the prints in the case of all three of the above solutions containing varying quantities of peroxide. The disadvantage of the 125/10 peroxide-ammonia mixture is its shorter exhaustion life as compared with the

500/10 mixture. For single-weight prints, a shorter wash will suffice. All prints must be washed for at least 5 to 10 minutes after the eliminator treatment.

A duplicate set of the prints shown in Fig. 4 was treated in a hydrogen peroxide solution for 5 minutes, washed for 5 minutes, and then subjected to the accelerated fading test at the same time as the

FIG. 5. Accelerated fading tests illustrating the effectiveness of the peroxide-ammonia hypo eliminator. The upper row of prints contained quantities of hypo designated in milligrams per square-inch and did not receive eliminator treatment. The lower row of prints contained same quantities of hypo and were treated 5 minutes in an eliminator solution consisting of 500 cc of 3 per cent hydrogen peroxide and 10 cc of 28 per cent ammonia per liter. They were then subjected to the same accelerated fading conditions. Note absence of fading.

prints which were not treated in the eliminator solution. The effect of the peroxide-ammonia eliminator in preventing fading is illustrated in Fig. 5.

An extensive study of the application of these solutions in the photographic trade was made with special attention to exhaustion life of the solutions, and to any possible deleterious effects in commercial processing. The specific application is dependent upon the use intended. At the outset, since it is never possible to predict the

conditions to which a print may be subjected, every photographer must eliminate the hypo completely from prints and negatives, even if this may require some slight modification of his processing machine or the method of working.

PRACTICAL RECOMMENDATIONS

With negatives and transparencies or, in general, any gelatin silver image on a waterproof support, if, during washing an adequate renewal of the wash water prevails, the hypo can be removed completely by water alone in a reasonable time at a temperature of 60° to 70°F without the use of a hypo eliminator.

If it is necessary to speed up the processing by using a shorter washing time, a supplementary alkaline bath may be used. After the negatives have been washed for 10 minutes, they should be bathed in an 0.3 per cent solution of ammonium hydroxide (100 cubic-centimeters of 28% ammonia per liter) for 3 minutes and then washed for 2 or 3 minutes.

The rate of washing is also hastened if a chrome alum or nonhardening fixing bath is employed.

With photographic prints, washing is hastened by using water at around 70°F, but it is never possible to remove the hypo completely by merely washing so that the print will not subsequently fade if subjected to abnormal conditions of temperature and humidity. The use of the following peroxide-ammonia eliminator is necessary to insure permanency:

KODAK HE-1

Hypo Eliminator Solution for Professional and Amateur Use

	Avoirdupois	Metric
Water	16 ounces	500.0 cc
Hydrogen Peroxide (3% solution)	4 fluid oz	125.0 cc
Kodak Ammonia (3% solution)	3 1/4 fluid oz	100.0 cc
Water to make	32 ounces	1.0 liter

To make 3 per cent ammonia, dilute 1 part of 28 per cent ammonia with nine parts of water.

Directions for Use.—Wash the prints for about 30 minutes at 65° to 70°F* in running water which flows rapidly enough to replace the water in the vessel

* For lower temperatures, increase the washing time. Double the washing time should be used when double-weight prints are treated.

(tray or tank) completely once every 5 minutes. Then immerse each print about 6 minutes at 70°F in the Hypo Eliminator Solution (Kodak *HE-1*), and finally wash about 10 minutes before drying.

Life of Kodak HE-1 Solution.—About fifty 8-inch × 10-inch prints or their equivalent per gallon (4 liters).

Test for Hypo.—Process with the batch of prints, an unexposed *white* sheet of photographic paper (same weight and size as majority of prints in batch). After the final wash, cut off a strip of this sheet and immerse it in a 1 per cent silver nitrate solution for about 3 minutes; then rinse in water and compare, *while wet* in subdued daylight or artificial light, with the *wet, untreated portion.* If the hypo has been completely removed, no color difference should be observed. A yellow-brown tint indicates the presence of hypo.* *Caution:* Silver nitrate solution stains the skin black; avoid direct contact with the solution.

* A positive test with silver nitrate may also be obtained in the absence of hypo, if hydrogen sulfide or wood extracts are present in the water supply.

KODAK HE-2

Hypo Eliminator Solution for Commercial Photofinishing Use

	Avoirdupois	Metric
Water	10 ounces	300.0 cc
Hydrogen Peroxide (3% solution)	16 ounces	500.0 cc
Kodak Ammonia (3% solution)	3¼ ounces	100.0 cc
Water to make	32 ounces	1.0 liter

To make 3 per cent ammonia, dilute 1 part of 28 per cent ammonia with nine parts of water.

Directions for Use.—Wash the prints about 15 minutes at 65° to 70°F* in running water which flows rapidly enough to replace the water in the washing vessel (tray or tank) completely once every 5 minutes. Then immerse each print for about 5 minutes in the Hypo Eliminator Solution (Kodak *HE-2*), and finally wash about 10 minutes before drying.

When using a Pako Print machine (or similar equipment), replace the water in the second wash tank with the Hypo Eliminator Solution (Kodak *HE-2*), and process the prints as usual.

Life of Kodak HE-2 Solution.—About eighty 8-inch × 10-inch prints or their equivalent per gallon (4 liters).

Test for Hypo.—Use the same test as recommended for use with Kodak *HE-1* Solution.

* For lower temperatures, increase the washing time. Double the washing time should be used when double-weight prints are treated.

The above treatment will insure the absence of fading from internal fading agents. However, a hypo-free image will be attacked by hydrogen sulfide which is present in the products of combustion of

coal gas and in the atmosphere of industrial regions. This external fading is accelerated by the presence of acidic gases and by high temperature and high humidity.

The use of water-miscible (paste) adhesives for mounting also contributes to fading, since such adhesives are usually hygroscopic and the resulting moist condition of the print is favorable to more rapid chemical reaction.

Fading due to external agents may be minimized by (*1*) the use of a waterproofing lacquer over the print surface, (*2*) the use of Dry Mounting Tissue, and (*3*) bathing the print in a solution of a salt of a noble metal, such as gold chloride (with sodium thiocyanate), when the metal ion displaces the outer layer of the silver grains, usually with a negligible change in image color. A suitable formula consists of gold chloride, 0.1 gram; sodium thiocyanate, 10 grams; dissolved in 1 liter of water.

It is essential that the solution be prepared just before use and in the following manner: Add 10 cubic-centimeters of a 1-per cent gold solution to a 1-liter vessel and dilute to approximately 700 cubic-centimeters. Dissolve the thiocyanate in a small volume of distilled water and add slowly to the gold solution with continuous agitation. Then make up to 1 liter with water.

Bathe either the freshly washed or dried prints for 8 minutes at 70° to 75°F with agitation or until a just perceptible change in tone occurs and then wash for 5 minutes before drying. The life of the bath if used immediately is approximately thirty 8-inch $\times$ 10-inch prints per gallon of solution.

The gold treatment also stabilizes the image against fading by hypo. It is not quite as effective, however, as the peroxide-ammonia treatment and has the disadvantage that the color of the image is changed slightly.

With respect to fading by hydrogen sulfide, lacquering the print surface is helpful but not as effective as the gold treatment. Dry mounting in combination with a lacquer is surprisingly effective, from which it is apparent that the hydrogen sulfide attacks the image appreciably from the rear through the paper stock as well as at the surface.

A combination of these procedures, namely, (*1*) use of the peroxide-ammonia hypo eliminator, (*2*) treatment with the gold solution, (*3*) the use of Dry Mounting Tissue, and (*4*) lacquering of the print surface, will insure maximum permanency of the gelatin silver print

image. Conversion of the silver image to silver sulfide by sulfide toning in the usual manner, or to silver selenide or telluride, will also insure maximum permanency, although such treatments change the color of the image.

OCCASIONAL EFFECTS WHEN USING THE PEROXIDE-AMMONIA TREATMENTS HE-1 AND HE-2

(*1*) A slight change in tone: This tone change is not as great as that produced by ferrotyping and, therefore, is considered to be negligible for glossy papers. When it is desired to prevent the slight tone change on professional papers, 15 grains of potassium bromide should be added to each quart (1 gram per liter) of the Kodak *HE-1* bath.

(*2*) A slight yellowing of the whites (undetectable on buff papers): To minimize this effect, the prints should be bathed in either a 1-per cent acetic acid solution or a 1 per cent sodium sulfite solution for about 2 minutes immediately after treatment in *HE-1* or *HE-2* and prior to the final wash.

(*3*) If the prints feel too slippery after the eliminator, they should be immersed for 1 minute in a 1-per cent solution of acetic acid and then washed for 3 or 4 minutes.

(*4*) A slight tendency for treated prints to stick to a hot belt dryer. To prevent this, the prints should be bathed, prior to drying, for 3 to 5 minutes in a 50-per cent denatured alcohol solution. A 2-per cent potassium alum solution is effective but requires a rinse of several minutes in water after the treatment.

(*5*) An occasional tendency for treated glossy prints to ride the squeegee roll of the ferrotype dryer (especially prints which have been accidentally fed into the machine emulsion side up), or to stick to the chromium drum itself. To overcome these difficulties, the prints should be bathed for 2 minutes in a 50-per cent denatured alcohol solution just prior to ferrotyping.

(*6*) While cleanliness of the drum surface is essential for the satisfactory ferrotyping of all prints, it is especially important as a sticking preventative in the case of peroxide-ammonia treated prints. Excessive drum temperatures should also be avoided.

RELATION BETWEEN THE THEORETICAL AND PRACTICAL QUANTITIES OF HYPO REQUIRED TO PRODUCE FADING

It is of interest to study the relationship between the theoretical quantity of sodium thiosulfate required to convert any given silver

image to silver sulfide and the quantities actually required to produce fading under accelerated conditions in practice.

The "photometric equivalent"[12] may be defined as the number of grams of silver in a 100 square-centimeter area of emulsion which are necessary to give a density of 1.00. Its magnitude varies with the exposure, the degree of development, and the grain size of the emulsion, ranging from approximately 0.005 to 0.035, depending upon the type of the emulsion.

Hickman and Spencer[13] calculated the quantity of thiosulfate required to react with the silver in an image having a density of 0.10 and made the assumption that only one-tenth of the silver need be sulfided to produce just visible fading, which seems reasonable. The reaction may be expressed by the equation

$$\underset{\text{Silver}}{2\,Ag^{+}} \; + \; \underset{\text{Thiosulfate Ion}}{S_2O_3^{--}} \longrightarrow \underset{\text{Silver Sulfide}}{Ag_2S} \; + \; SO_3^{--}$$

To express the quantity of thiosulfate in milligrams per square-inch which is required to fade an image of density 0.10, the following formula was employed:

$$\begin{array}{c}\text{Photometric Equivalent} \times \dfrac{\text{Molecular Weight of Sodium Thiosulfate}}{2\times \text{ Atomic Weight of Silver}} \times \dfrac{\text{Conversion Factor}}{\text{Metric to Avoir.}} \times 10\% \times 0.1 \\ \| \\ \text{Photometric Equivalent} \times \dfrac{248}{215} \times \dfrac{6.45 \times 0.1 \times 0.1}{100 \times 1000}\end{array}$$

The sulfiding reaction first occurs visibly in the low densities having a value of approximately 0.10. The photometric equivalents at low densities are given in Table IV and also the theoretical quantity of thiosulfate required to produce fading at a density of 0.10. Included in the same table are limiting concentrations of hypo above which fading occurred under the conditions of the accelerated fading test.

In general, the faded images with the intermediate and high-speed materials possessed a purplish-black coloration not greatly different in appearance from the original and often of similar printing density. The images of motion picture positive emulsions became more yellowish-brown than those of the high-speed materials but only when the hypo content was in considerable excess of 0.07 milligram per square-inch. With the finest-grained materials, a definite yellowing occurred at concentrations of thiosulfate greater than 0.02 milligram per square-inch.

A comparison of the theoretical values given in Table IV with the quantities determined by experiment reveals that (*1*) with chloride paper emulsions the hypo content should not exceed 0.002 to 0.005 milligram per square-inch or 0.02 milligram per square-inch with chlorobromide emulsions; (*2*) with film emulsions, in general, more hypo is allowable than the calculated theoretical value, for example, (*a*) fine-grain materials 2 to 3 times, and (*b*) with negative materials, 4 to 9 times. This indicates that when a safety factor of 10 is assumed in the determination of the quantities of hypo required to fade images, in general, the formula is applicable only to paper emulsions. With film emulsions, it is apparently necessary to convert from 25 to 50 per cent of the total mass of the image to silver sulfide before the image color changes appreciably.

TABLE IV

Material	Density at Which Photometric Equivalent Was Measured	Photometric Equivalent at Indicated Density	Calculated Quantity of Hypo (Mg per Sq-In) Required to Cause Fading at Density of 0.1	Concentration of Hypo Required in Practice* (Mg per Sq-In)
Chloride paper emulsions			0.005**	0.002–0.005
Chlorobromide paper emulsions†	0.25	0.0087	0.007	0.02
	0.08	0.009	0.007	
Fine grain lantern slide[14]	1.00	0.005	0.008	0.02
Fine grain emulsion	0.47	0.0108	0.008	
Process emulsion[15]	0.13	0.0153	0.011	0.07
Process emulsion[15]	0.09	0.0235	0.018	
Commercial emulsion[15]	0.13	0.0226	0.017	0.14
	0.56	0.0228	0.017	

* These figures represent average values for the types of materials mentioned.

** Chloride emulsions are more fine-grained than chlorobromide emulsions and the photometric equivalent is probably as low as 0.005.

† Unpublished results—S. E. Sheppard and A. Ballard, Kodak Research Laboratories.

All the types of emulsions mentioned are readily washed to the degree indicated in Table IV and, in good commercial practice, are usually washed to concentrations well below those given. Process, motion picture positive, and fine-grain emulsions, for example, often contain as little as 0.005 milligram per square-inch, as determined by the Crabtree-Ross method. This method of analysis has been adopted by the National Bureau of Standards.[16]

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[11] Footnote, *Das Lichtbild*, **7** (1931), p. 42.

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[16] "Evaluation of Motion Picture Film for Permanent Records," *Misc. Pub. M-158, U. S. Dept. of Comm.*, National Bureau of Standards (1937), p. 5.

CHRONOLOGICAL HISTORY OF HYPO ELIMINATORS

1855. **Alum:** "On Positive Printing," by J. Newton (*J. Phot. Soc.*, **31**, June 1855, p. 176) ". . . immerse in hyposulfite for about 2 or 3 minutes, then

in alum water for half an hour and change the water entirely two or three times."

1855. **Caustic Potash:** "Communication on Positive Photographs," by Mr. Malone (*J. Phot. Soc.*, **31**, June 1855, p. 177) "I suggest that you should treat the positive photograph, fixed in the ordinary way, with a strong solution of caustic potash heated to about 180° Fahrenheit; . . . carefully washing out the potash."

1856. **Dilute Alkali or Alkaline Carbonate:** "Photographic Chemistry," by F. Hardwick, *Churchill, London* (3rd Ed., 1856, p. 170). ". . . and the removal of the size which can be effected by means of a dilute alkali or an alkaline carbonate, . . . has the additional advantage of carrying out the last traces of hyposulfite of soda. . . ."

1864. **Hypochlorous Acid:** "Minutes of Meeting of South London Photographic Society," by F. W. Hart (*Brit. J. Phot*, **11**, March, 1864, p. 82). Suggested the use of chlorine and barium chloride in aqueous solution to convert hypo to barium sulfate and sodium chloride.

1866. **Hydrogen Peroxide:** "On the Removal of the Last Traces of Hyposulfites from Positive Paper Prints," by A. Smith (*Brit. J. Phot.*, **13**, May, 1866, p. 226). Recommended the use of hydrogen peroxide, diluted with one thousand times its volume of water, for one or two minutes. Advised the neutralization of the acid in the peroxide with soda. The treatment required a rinse in water as the final operation.

1866. **Hydrogen Peroxide and Ammonia:** "Photography in Its Chemical Aspects," by J. Spiller (*Phot. J.*, **11**, June 1866, p. 58). Used hydrogen peroxide with ammonia but claimed that the two were "mutually decomposed." Then suggested treating first in hydrogen peroxide followed by ammonia. *Note:* A discussion of this paper, reported in *Brit. J. Phot.*, **13**, 1866, p. 283, recommended treating the prints first in ammonia and then in hydrogen peroxide.

1866. **Sodium Hypochlorite:** "On the Elimination of the Double Hyposulfites of Soda and Silver from Photographic Prints," by F. W. Hart (*Brit. J. Phot.*, **13**, June, 1866, p. 290). Recommended sodium hypochlorite followed by very dilute ammonia to dissolve traces of silver chloride.

1866. **Chloric and Perchloric Acids:** Editorial—"Permanent Prints: A New Plan," by Messrs. Tichborne and Robinson (*Brit. J. Phot.*, **13**, Dec., 1866, p. 580). Twenty-four grains of barium chlorate are dissolved in one ounce of water and 20 minims of 12 per cent perchloric acid added. For use add 2 ounces of this solution to one pint of hot water. Treat prints for about an hour and wash in water.

1872. **Iodine:** "The Chemistry of Photography," by W. Harrison (*Scovill and Adams Co., New York, N. Y.*, 1892, p. 412). Vogel is credited with the first use of iodine. After careful washing the prints were placed in water to which enough iodine solution was added to give it a sherry color; then rinsed in a very weak solution of sulfite and sodium carbonate to remove the blue color and finally washed in water.

1881. **Alum:** "Notizen zum Bromsilber—Gelatine Verfahren," by J. M. Eder (*Phot. Korr.*, **18**, 1881, p. 203). Used a saturated solution of alum diluted one to ten with water.

1881. Zinc Hypochlorite: L. Belitzski and G. Scolik (*Eder's HandbuchPart III, Knapp, Halle* (4th Ed.), 1890, p. 317). Used in dilute water solution. Known as Flandreaus' eliminator in America.

1883. Bromine Water, Etc.: "Die Beseitigung des unter schwesligsauren Natrons," by F. Stolze (*Phot. Wochenblatt*, 1883, p. 348). Javelle water, hydrogen peroxide, iodine water, bromine water, lead nitrate, and barium nitrate are discussed. Alum with citric acid in water was suggested. Successive five-minute treatments were used and the wash water tested after each wash. None of these was considered entirely satisfactory.

1888. Hypo Eliminator: "Early History of Hypo Eliminators," by F. W. Hart (*Brit. J. Phot.*, **35,** 1888, p. 151). The claim to the original use of the term "hypo eliminator" is made.

1889. Sodium Chloride: Editorial (*Amer. Phot.*, **19,** 1899, p. 38). Reference to the use of sodium chloride as an eliminator by Dr. Bannon but no directions are given.

1894. Potassium Persulfate: Mention of its use by Schering is made by L. P. Clerc in his book "Photography—Theory and Practice," *Pitman, London,* 1930, p. 269.

1897. Iodated Salt: "Sel Iode Eliminateur Rapide des Hyposulfites," by M. P. Mercier (*Bull. de la Soc. Franç. de Phot.*, **30,** 1897, p. 296). A suggested formula was iodine 3 parts, salt 30 parts, and sodium carbonate 30 parts dissolved in 1000 parts of water. "Decolorize with ammonia just before use. The print may be left in this solution for a long time because the colorless solution does not attack the silver image. Iodine or iodides may be used with alkali or alkali salts and bromine or bromides may be used but the latter are much slower acting."

1901. Potassium Percarbonate: Use by G. Meyer is mentioned by L. P. Clerc in his book "Photography—Theory and Practice," *Pitman, London,* 1930, p. 269. No directions are given.

1902. Ammonium Persulfate: "Use of Various Oxidizers for the Destruction of Hypo," by A. and L. Lumière and A. Seyewetz (*Bull. de la Soc. Franç. de Phot.*, **10,** 1902, p. 270). Hydrogen peroxide, potassium percarbonate, and commercial ammonium persulfate were the best hypo oxidizers but ammonium persulfate was the most practical provided the free acid was first neutralized with either carbonate, bicarbonate, alkaline phosphates, alkaline citrates, alkaline tungstate, or borax. Low concentrations were satisfactory.

1903. Alkaline Perborates: G. F. Jaubert. Mentioned by L. P. Clerc in his book "Photography—Theory and Practice," *Pitman, London,* 1930, p. 269. No directions given.

1903. Sodium Chloride: O. Baysellance (*Phot. Rev.*, **12,** July 26, 1903, p. 32). "Treat $^1/_2$ to one hour in 3-per cent sodium chloride and then give three or four rinses in water."

1904. Potassium Permanganate: "Permanganate as an Eliminator of Hypo," by I. Pearse (*J. Phot. Soc. India*, 1904; *Cf. Photography*, **20,** 1905, p. 197). Use water slightly colored with permanganate and use successive solutions until no change in color occurs. Less than ten minutes of this treatment was equal to two hours washing.

1912. **Bisulfite-Formaldehyde:** "A Hypo Remover," by E. D. Davison (*Camera Craft* **19,** 1912, p. 30). Recommended water 40 parts, sodium bisulfite 3 parts, and formaldehyde 8 parts. Treat prints (after washing) for 10 to 15 minutes in a solution diluted 1:3 with water.

1922. **Chloramine T (Sodium *p*-toluene Sulfochloramide):** "A New Quick Clean Eliminator of Hypo," by E. F. Shelberg (*Amer. Phot.*, **16,** April, 1922, p. 267). Dissolve one tablet in 40 oz water and treat for two or three minutes, washing before drying.

1923. **Dilute Sodium Carbonate:** Unpublished data on the use of alkalies in hypo eliminator by F. J. Norton and J. I. Crabtree (*Kodak Research Laboratories*) July-August, 1923. Dilute solutions of sodium carbonate were recommended for use immediately after fixing.

1923. **Alkali Carbonate or Phosphate:** "Adsorption of Sodium Thiosulfate by Photographic Paper," by A. Charriou (*Compt. Rend.*, **177,** 1923, p. 482). Claimed that hypo was displaced more readily by washing in a solution of alkali carbonate or phosphate than by water.

1925. **Ferrous Sulfate:** "Hypo Eliminators and Intensifiers." Brit. Pat. 225,664, Oct. 9, 1923 (*Brit. J. Phot.*, **72,** 1925, p. 24). Three parts ferrous sulfate and one part sodium chloride were thoroughly mixed. Prints were treated in a solution containing 8 grains of this mixture in $1^1/_2$ pints of water and washed before drying.

1925. **Sodium Hydroxide:** "Hypo Eliminator," by A. E. Amor (*Brit. J. Phot.*, **72,** 1925, p. 18). Claimed that 0.2 per cent sodium hydroxide and a persulfate formula of the following composition were most effective eliminators but neither was an improvement over careful washing: Persulfate 6 grams, sodium carbonate 12 grams, water 1000 cubic-centimeters.

1931. **Sodium Hypochlorite Plus Sodium Chloride:** R. Namias (*Il prog. fot.*, **38,** 1931, p. 125). This combination was an improvement over hypochlorite alone. Negatives were washed five minutes, treated in 0.3 per cent sodium hypochlorite plus 1 per cent sodium chloride solution and washed for one or two minutes.

1931. **Hydrogen Peroxide Plus Ammonia:** Note in *Das Lichtbild,* **7,** 1931, p. 42. Ammonia was added dropwise until the solution just smelled of ammonia.

1932. **Dilute Caustic Soda:** "The Use of Alkalies as Hypo Eliminators," by E. E. Jelley (*Phot. J.*, **72,** 1932, p. 480). Kodak Research Laboratories Communication No. *503H.*

1937. **Sodium Carbonate 1%:** "On the Possibility of Improving the Permanence of Photographic Prints," by E. Weyde (*Veröff. wiss. Zentral-Lab. phot. Abt. Agfa,* **V,** 1937, p. 181). Also, *Brit. J. Phot.*, **82,** 376, June 14, 1935, p. 376, and *Photo Woche,* **25,** 1935, p. 474. For best hypo elimination the use of a nonhardening fixing bath followed by bathing in 1 per cent sodium carbonate before washing was recommended.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

A NEW RECORDING MACHINE COMBINING DISK RECORDING AND MAGNETIC RECORDING, WITH SHORT REFERENCE TO THE PRESENT STATUS OF EACH*

S. J. BEGUN**

Although there seems to be no doubt that sound-on-film will retain its predominant position in the screen entertainment field, on the other hand, there can be no question that the talking motion picture will also be used more and more in the home entertainment field; and recording methods other than optical may prove superior and better adapted to this application. Furthermore, for many years, disk recording has been used in the recording studio to give the recording engineer an opportunity to check the quality of the recording without having to wait for the development of the film. In certain cases, even re-recordings have been made from disk to the film, and there frequently may be occasions where re-recording from one recording medium to the other may be quite recommendable. By using the method of re-recording more frequently, film material may in many cases be saved, and the considerable expense for film that now has to be thrown away may be considerably reduced, particularly if the other recording materials are cheaper per unit time than the film.

It seems timely, therefore, to discuss two methods of recording other than the sound-on-film process, with which the sound-film engineer is so familiar. These two methods are disk recording and magnetic recording. As a result of considerable work that has been done on these two methods in the past few years, they are both capable of really high-fidelity reproduction of a signal.

DISK RECORDING

So far as disk recording is concerned, recording and reproducing a frequency range flat up to 10,000 cycles with negligible distortion is more than a theoretical ideal—it is a proved possibility. Listeners, including sound engineers, who have heard such recordings played in conjunction with an excellent sound system have remarked upon the brilliancy and cleanness of reproduction now obtainable. While the writer is quite aware of the good results to be obtained with studio film

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* Presented at a Meeting of the Atlantic Coast Section, April 17, 1940.

** Brush Development Co., Cleveland, Ohio.

recordings, he dares to say that the present high-fidelity disk recordings are, in every way, equal to, if not better than, the best that has so far been accomplished with film recording.

With professional disk recording equipment very good results have been obtained for the last few years. But such professional equipment has been quite expensive. The best proof of the considerable progress in the disk recording field is the fact that home recording units, even in the low-price range, will soon be available. These units will have a quality of performance comparable to that of radio chain programs. This progress has been possible only because the development laboratories have been busy investigating the important factors controlling the quality of recording, and analyzing the problems that for many years have been neglected.

Disk recording, or as it should be called, mechanical recording, can look back upon a history of almost sixty years. Only lately, however, have the engineers been able to improve the various components in the recording and reproducing chain to such an extent that really high-fidelity performance can be obtained.

A disk recording unit consists of four essential parts—the turntable, the disk cutting device, the disk material, and the reproducer. Microphone, amplifier, and loud speaker are also parts of the complete system, but they will not be discussed in detail in this paper.

The Turntable.—The turntable includes the motor, with its drive for the turntable proper, and the feed mechanism for moving the motor along a radius of the disk from the inside outwardly or *vice versa.* It is well known that during the recording and playback process, constancy of speed is an essential factor for any recording device. In general, two kinds of speed variations can be distinguished: one causes a slow periodic change of speed, the other, a fast periodic change of speed. The low-frequency speed changes are evidenced by a waver known to the profession as "wow," and which is particularly objectionable in long, sustained notes. The higher-frequency speed changes, on the other hand, may not be noticeable to the ear as such, but will cause distortions of an objectionable character. An otherwise clean sinusoidal tone, when reproduced by a system having this high-frequency flutter, will sound badly distorted.

Furthermore, a turntable should be as free from mechanical vibration as possible. Since the recording and reproducing process is essentially a mechanical process, such mechanical vibration, being of the same nature as the recorded signal, will produce, during the playback, a signal pick-up technically described as "rumble." The intensity of these vibrations, in the case of a poor turntable, may be so great as actually to overload the playback amplifier, producing distortion and cross-modulation of the useful signal.

Producing a satisfactory turntable is much more of a problem than it seems at first glance. There are in general two methods of building a turntable in order to approach the requirements of a flutter-free and rumble-free drive. One method is to use what may be called a "brute force" design. This involves a very massive turntable and a comparatively small driving force, coupled flexibly one to another.

A very satisfactory example of this method is the use of a string drive coupling a synchronous motor to such a heavy turntable. Fig. 1 shows the principal parts of such a design. A turntable drive built after this fashion is in use in these

laboratories and performs very satisfactorily. It is advisable in discussing the design principles of such a turntable to emphasize the fact that the driving motor must have sufficient power, with some reserve to provide the necessary torque. On the other hand, however, the motor should not be so powerful that its unavoidable speed variations are delivered in sufficient force to influence the smooth rotation of the turntable. In this connection, it should be pointed out that even synchronous motors are not entirely free of speed variations. Even though these motors turn, on the average, in accurate synchronism with the supply frequency, during a revolution the armature may not always move with constant angular velocity, and may "hunt" considerably about a mean average speed.

If "brute force" filtering is not used, it is necessary to incorporate a filter as part of the transmission member between the motor and the turntable. This is usually done by providing a low-pass mechanical filter, using one or more stages of inertia and stiffness members. Some of these filters are rather com-

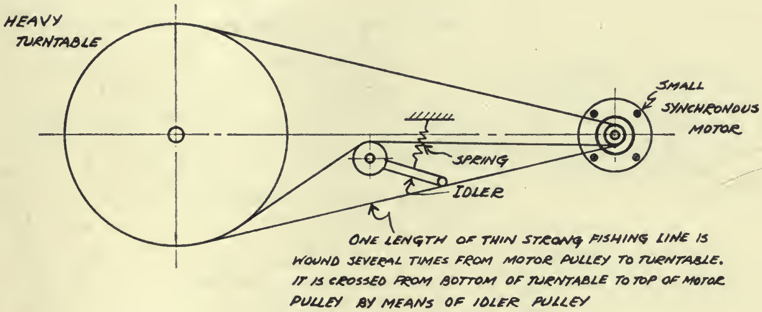


FIG. 1. String-driven turntable.

plicated, but the most prevalent today, which is apparently reasonably satisfactory (at least for the home recording field), is the turntable rim drive.

Such a drive is shown in Fig. 2. It consists of a motor engaging the rim of the turntable by means of a rubber pulley. In this case, the mass of the filter is represented by the turntable and the armature of the motor, and the stiffness is provided by the resilience of the rubber pulley.

There are several variations of the rim drive. One is provided by covering the inside rim of the turntable with a rubber tire which is engaged by the metallic motor pulley; another is provided by an intermediate rubber wheel which engages a metallic motor shaft on one part of its circumference, and a metallic turntable rim on another part. Some of these rim-driven turntables are surprisingly free from flutter, and such designs seem very promising. The simplicity of the rim-driven turntable will undoubtedly popularize it, particularly in the low-price field. In addition, relatively inexpensive provisions can be made for changing the turntable speed from 78 to $33^1/_3$ rpm.

There are also turntables incorporating gear trains. Some of these turntables give very satisfactory results, but require very carefully machined gears, and are therefore extremely expensive. Some other turntables of this kind, how-

ever, are inferior, as insufficient care is taken in their engineering. If a turntable of this class is to be used, extreme care must be given to the selection of proper equipment.

The Feed Mechanism.—Regarding the feed mechanism, any such device will be satisfactory if it has no backlash and provides a smooth progression across the radius of the disk, either inside out or *vice versa.* Preferable are those feed mechanisms that move the cutter along a diameter across the disk, thus providing regular groove spacing with no tracking error. Any high-fidelity instrument should be equipped with a feed mechanism of this design characteristic. So far as the less expensive recording turntables are concerned, the feed mechanism must be simple and inexpensive. In this case, the cutter may be held in an arm like a pick-up, and moved in an arc. By offsetting the cutting head on such an arm, the tracking error can be greatly reduced to the point where it is no longer a serious problem.

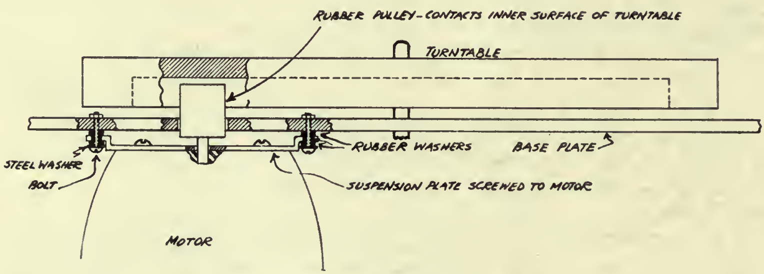


FIG. 2. Rim-driven turntable.

An arm moving in an arc may be coupled to the turntable or may be driven independently. In either case, feed mechanisms have been built of sufficiently good accuracy for most ordinary work. One of the most common feed mechanisms used in lower-priced recorders is illustrated in Fig. 3.

The independently driven feed mechanism may have the advantage of greater flexibility. This makes it possible to change the spacing between the grooves over a wide range without necessitating a change in the ratio of reduction of the gearing arrangement. This change would be necessary in the case of a direct drive on the turntable.

Cutting Head.—The next important component in the recording system is the cutting device, generally referred to as the cutter or cutting head. The principal requirement of the cutter is to cut a mechanical facsimile of a given sound-wave into the recording material. To do this, the cutter must be quite independent of any load imposed by the cutting medium. This is required particularly because of the fact that the load imposed by the cutting medium may vary not only with the depth of cut, but also with different mediums. To provide a sufficient reserve of force in the cutting device, the internal impedance of the cutter should be considerably higher than the external resistance imposed upon any cutting medium. This high internal impedance may be achieved either by

a high order of damping, or by making the stiffness force of the cutter greater than the external loading over the useful frequency range.

With respect to the use of considerable internal damping of the cutter, it should be pointed out that such an arrangement has the inherent disadvantage that all damping materials change their coefficients of friction considerably with temperature. Cutters of this kind, therefore, should be used in temperature-controlled rooms. On the other hand, a stiffness-controlled cutter will not be greatly affected by temperature variations below its resonance point. In a high-fidelity cutter, it is probable that a combination of the two methods would be desirable. However, for the design of a lower-priced recording instrument, it

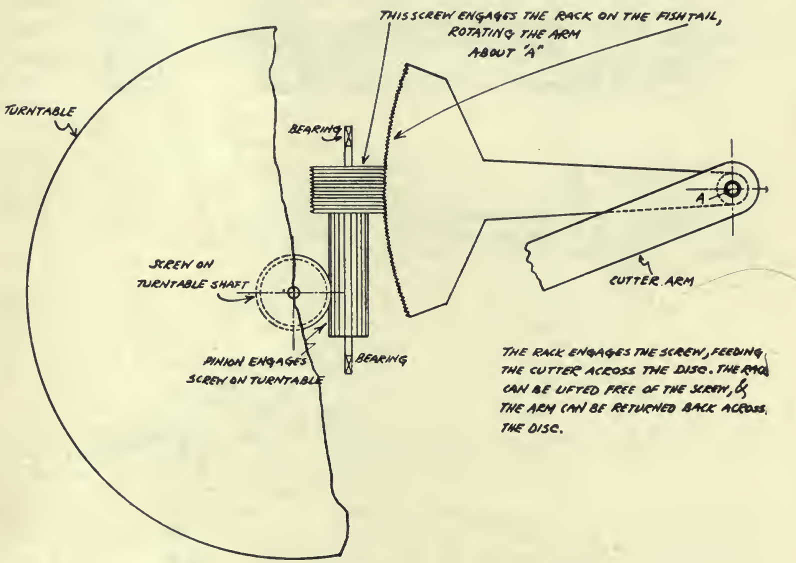


FIG. 3. Feed mechanism.

is better to depend more upon the stiffness of the cutter than upon the damping, since such a cutter will be used under varying temperature conditions.

Since a high order of internal stiffness is desirable, the Rochelle salt crystal lends itself admirably as a motor unit in a cutter. Such a crystal cutter is shown in principle in Fig. 4. A four-ply crystal element is held by Koroseal pads. This gives not only a very stiff mounting support, but also some damping, which reduces the peak at the natural frequency of the cutter. The stylus chuck is connected to one end of the crystal element, and because this stylus holder differs greatly from the usual stylus mountings, a short explanation may be of interest.

The stylus holder has a *V* groove, bent in the form of an arc, as shown in Fig. 4. This permits the stylus to rest upon two points. An important feature of this design is that the set-screw is mounted in the cutter housing in such a way

that its axis is on the neutral axis of the crystal. Therefore the set-screw does not participate in the motion of the stylus, but provides only the third point of support for it. This design eliminates any additional inertia inherent in the usual stylus mounting. The reason for forming the chuck as described is to give the stylus such a support that the overhanging end of the stylus is small. Experiments have indicated that some commercial styli have a tendency to break up when cutting the higher frequencies. This can be eliminated if the stylus is supported as described.

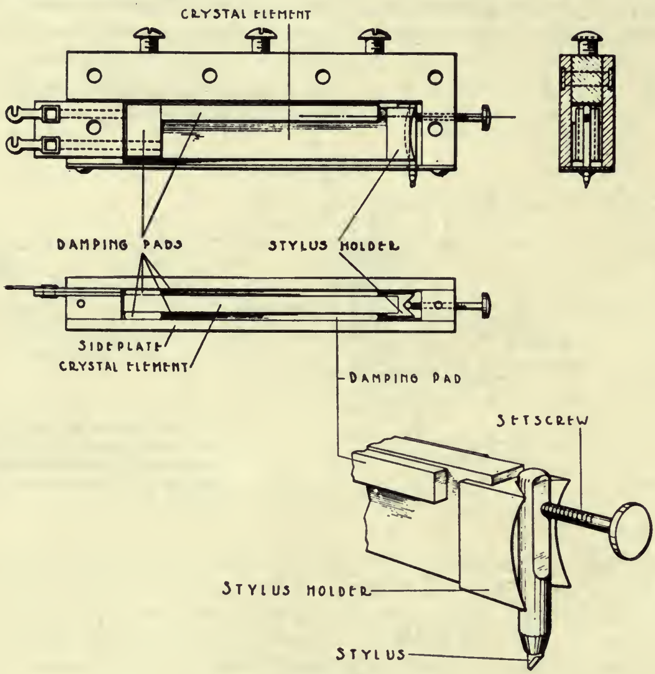


FIG. 4. *RC-20* cutter.

Fig. 5 shows the frequency response, as well as the harmonic distortion content as a function of frequency, of the cutter previously described. This cutter was developed with the intention of using it in the home recording field. It does not represent, therefore, an expensive unit. Its characteristics, nevertheless, are much superior to those of cutters generally available in the past in the much higher priced class.

Following the design principles established for this cutter, and keeping in mind the requirements pointed out in connection with general cutter design, there seems to be no difficulty in engineering a cutter that will meet the highest requirements of professional work. Crystal cutters are now available that are free from objectionable peaks and dips, and have a flat frequency range up to 11,000 cycles.[1]

It was mentioned before that the depth of cut is one of the variables with respect to the external loading of the cutter. The relationship between depth of cut and the required cutting force has been investigated. It was found that the force required is proportional to the cross-section of material removed from the record during the cutting process. By "cutting forces" is meant not only the torque that must be supplied to the turntable by the motor, but also the force that the cutter must supply to move the stylus in the cutting medium. The fact that the cross-section is approximately proportional to the square of the depth of cut for the conventional cutting stylus requires that for twice the depth, four times the force is required from both turntable and cutter. In Fig. 6 is shown the force supplied by the turntable as a function of the depth of cut for a representative direct recording medium. Experiments have shown that the speed of the turntable in its useful range has little influence upon these forces. Regardless of whether the turntable speed is 78 or $33^1/_3$ rpm, the cutting forces are not greatly altered.

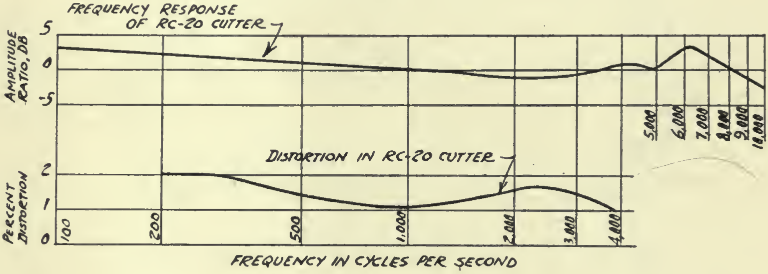


FIG. 5. Constant-amplitude characteristics of *RC-20* crystal cutter; recording at 22 db power level; amplitude of cut, 0.6 mil at 500 cycles. (Distortion curve weighted for probable peak amplitudes.)

After these considerations, it seems timely to consider whether any variations in depth of cut are to be expected during the cutting procedure. Regardless of whether the depth of the cutter is controlled by an advance ball or by a spring balance, certain differences in depth of cut may be expected, due to the unevenness of the disk material used. Any slight elevations in the surface of the disk will react upon the mass of a balanced cutter to produce variations in depth of cut. If an advance ball is used, this ball must be extremely close to the stylus point to eliminate all depth variations.

Of course, this factor of variation of depth of cut is a function of the material. The better cellulose nitrate disks with a heavy aluminum base are quite uniform, and cause inappreciable trouble with respect to depth of cut. But disks of this kind are very expensive, and probably are used only for high-fidelity studio recordings. For the less expensive type of recording machines where, because of economic reasons, cheaper disk material must be provided, the disks show considerable variations with respect to uniformity of surface. For this type of machine, it is essential that a spring-balanced cutter be used, and that the cutter have a very low moment of inertia in the vertical plane so as to minimize varia-

tions in depth of cut. On the other hand, the cutter should be mounted in such a way that the coupling between the cutter and the mass of the cutter arm will be great enough so that the stylus will have a stationary point from which to move in the horizontal plane.

Disk Materials.—The next important member in the recording chain is the disk material. Disk materials have already been briefly referred to, but the point will now be discussed in more detail.

For several years, cellulose nitrate disks have been used successfully for professional work. Lately these materials have been improved, particularly from the standpoint of uniformity of manufacture. The signal-to-noise ratio has also been raised. These records have one deficiency, however—they age, and thus change somewhat the characteristics of the recording. For the home recording

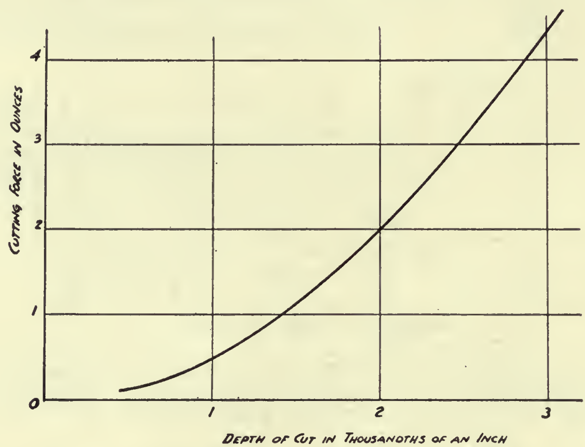


FIG. 6. Cutting force as a function of depth of cut.

field, they have the additional disadvantage that the nitrate chips are highly inflammable, and thus constitute a fire hazard. Furthermore, such disks are, for the time being, too expensive for the home recorder market, which requires fairly inexpensive disk material.

Because of the general success that the radio-recorder combination has already met, however, the industry is trying to solve the problem of a good, yet inexpensive, disk material. It has been attempted, experimentally, to cut much harder materials than cellulose nitrate, and some were found to be quite promising. These harder materials have not had much of a chance with most of the magnetic cutters, since these cutters, for the greater part of the audible range, are inertia-controlled; they do not provide sufficient energy reserve to overcome the external loading of a harder medium. The crystal cutter, however, because of its intrinsic high stiffness, is well adapted to cutting these harder materials. It can be safely assumed that the next year will show a great number of different disk materials on the market, and it is hoped that some of them will be

inexpensive, non-inflammable, and yet capable of giving a satisfactory reproduction with a good signal-to-noise ratio.

The Pick-Up.—The last member in the recording and reproducing chain is represented by the pick-up. For many years, the pick-up was one of the weakest links because of its high mechanical impedance, which requires an excessive needle pressure in order to secure adequate coupling to the record grooves. The combination of high stylus pressure with the high needle inertia quickly wears away the high-frequency modulations, introducing distortion and raising the noise-level of playback considerably.

Only lately, after the introduction of reproducers with permanent stylus points, has it been possible to reduce the mechanical impedance and stylus pressure to such an extent that practically negligible wear takes place during the

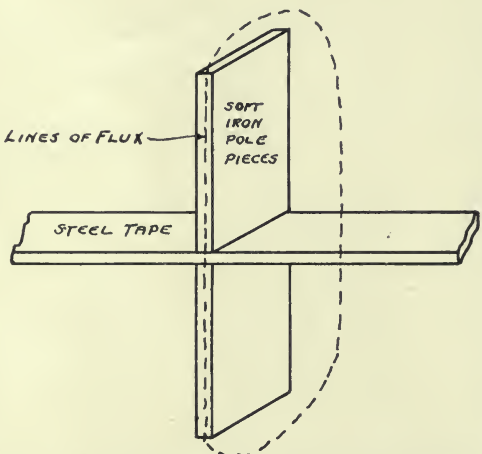


FIG. 7. Pole-pieces for perpendicular magnetization.

reproducing process; neither low nor high-frequency modulations are harmed by the passing stylus tip. Whereas a few years ago, a pick-up with a stylus pressure of three to four ounces was the usual design, the picture is quite different today. Pick-ups are now available for studio applications having as little as one-half ounce of needle pressure, and as little as one ounce of needle pressure for the broad commercial market. In the opinion of the writer, the crystal is ideally suited for the design of a light-weight record reproducer, since the moment of inertia of the vibrating system of the pick-up can be reduced practically to the motion of the permanent stylus point.

It seems worth while to mention briefly something about the different characteristics used in recording. It has been general practice to use the so-called constant-velocity characteristic for commercial pressings. With this characteristic, the amplitude of recording is inversely proportional to the frequency. The constant-velocity characteristic is used only for a certain frequency range, usually

above 500 cycles. Below 500 cycles, on the other hand, a constant-amplitude characteristic is used, the amplitude remaining constant and independent of frequency, with reference to a given input signal.

Lately a number of other frequency characteristics have been recommended, namely, the constant-amplitude characteristic, and the so-called orthacoustic characteristic. The constant-amplitude characteristic[2] refers to a method in which all modulations independent of frequency are cut with the same amplitude for the same input signal. The orthacoustic characteristic is a compromise between the constant-amplitude and the constant-velocity characteristic. In the home recording machines, the constant-velocity characteristic is used for the time being, so that the pick-up will reproduce commercial records and home recordings equally well. It can be assumed, however, that eventually a recording

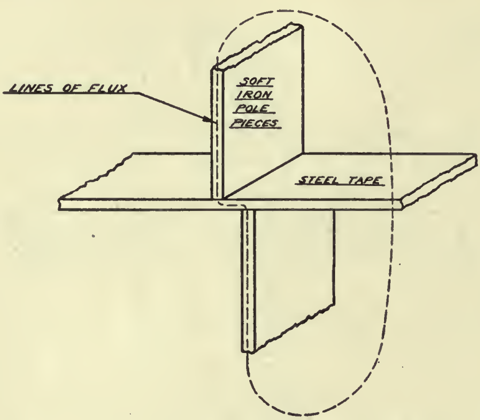


FIG. 8. Pole-pieces for longitudinal magnetization.

characteristic giving better results than the presently used constant-velocity characteristic will become available.

THE TAPE RECORDER

While magnetic recording also has a goodly heritage of years, having first been conceived some forty years ago, it has been only during recent years that systematic developmental work has been done with this kind of recording medium.

Its outstanding characteristic is that a recording can easily be used for any number of playbacks without substantial change of the playback characteristic; or the recording can be instantaneously obliterated, and the same medium can be used for other recordings. These processes do not in any way harm or use up the recording medium. Because of these characteristics, magnetic recording lends itself readily to any application where it is desired to reproduce a record a great number of times, or where it is desired to obliterate one record quickly, and record another. As a training and rehearsal device for artists, magnetic

recording machines have a unique position, since they may be used as many times as desired without loss of any material. Therefore the first commercially released magnetic tape recorder was developed for educational applications.[3]

These machines incorporate an endless steel tape having a recording time of approximately one minute. The endless tape has been provided to simplify the operation of the units to the point where it is required only to turn a knob and talk into a microphone. The machine automatically times itself and reverts from recording position to playback at the expiration of the available tape time.

FIG. 9. Tape recorder in cabinet.

It should be pointed out that, in general, there are two different methods of magnetic recording. In perpendicular recording the two pole-pieces are aligned, on opposite faces of the tape in the same plane. The magnetic flux acting on the tape is perpendicular to the axis of the moving tape,[4] as shown in Fig. 7.

Longitudinal magnetization, on the other hand, requires that the two pole-pieces on the opposite faces of the tape be slightly offset so that the main recording flux penetrates the tape in the direction of the axis of the tape,[5] as shown in Fig. 8.

Briefly, the process of magnetic recording consists of three functions—obliterating, recording, and playback. The most commonly used method of obliterating

is magnetically saturating the tape by subjecting it to a very strong magnetic field. Other methods have been successfully employed, but thus far are not in commercial use.

In the recording process the signal current is superimposed upon a polarizing current so as to obtain a unidirectional pulsating magnetic flux for any particle of the tape passing under the recording pole-pieces. It is quite important that the recording flux be unidirectional, since magnetic processes are not reversible.

In the reproduction process, the magnetic flux of the tape threads through the pick-up pole-pieces which, as in recording, are located on opposite sides of

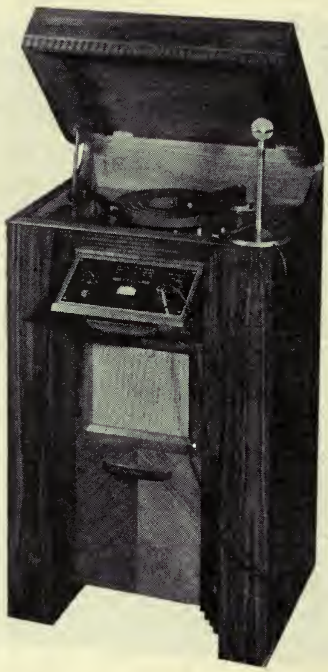


FIG. 10. Combination tape and disk recorder in cabinet.

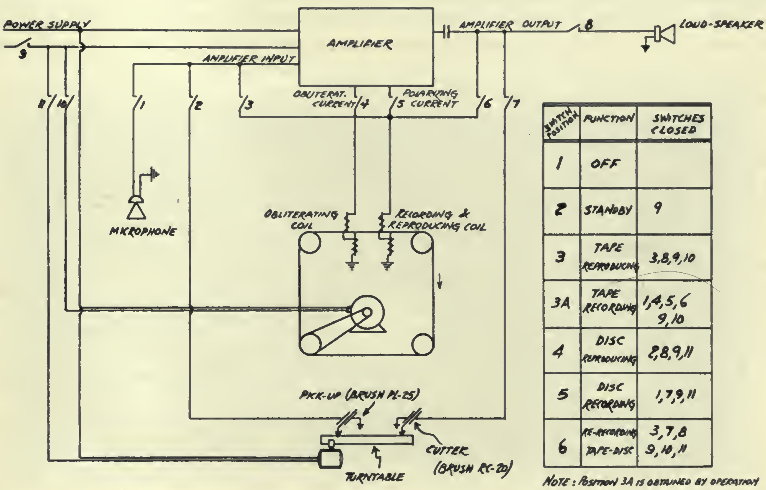
the tape, and for longitudinal recording, are slightly offset. This produces a potential across the pick-up coils.

The frequency range obtainable with magnetic recording is a function of three variables—the speed of the tape, the equalization in playback and recording, and the width of the pole-pieces used to record and pick up the signal. By suitably adjusting these three variables, any desired frequency range may be obtained. The width of the pole-pieces in conjunction with the separation of the planes of the two pole-pieces represents, so to speak, the "slit-width" of the system. The smaller and more accurate the "slit-width" is kept, the lower the

tape speed should be to obtain equivalent results for a given frequency response.

The commercial machines now on the market have a tape speed of approximately $3^1/_2$ feet per second, and are able to give a substantially flat frequency response up to 6000 cycles. These machines have a signal-to-noise ratio of somewhat more than 40 db, and meet most of the requirements of the applications for which they are designed. Fig. 9 shows a unit mounted in an attractive wooden cabinet, ready for operation.

Because the tape recorder uses up no expensive recording material, it may well be that the time will come when all motion picture sound recordings will be made on magnetic tape. Magnetic recording offers also the great advantage of almost instantaneous playback, without the necessity of any intermediate developing



SWITCH POSITION	FUNCTION	SWITCHES CLOSED
1	OFF	
2	STANDBY	9
3	TAPE REPRODUCING	3,8,9,10
3A	TAPE RECORDING	1,4,5,6 9,10
4	DISC REPRODUCING	2,8,9,11
5	DISC RECORDING	1,7,9,11
6	RE-RECORDING TAPE-DISC	3,7,8 9,10,11

NOTE: POSITION 3A IS OBTAINED BY OPERATION OF TIMER SWITCH WHICH FUNCTIONS ONLY WHEN MAIN SWITCH IS ROTATED TO POSITION 3.

FIG. 11. Diagram of combination tape and disk recorder.

and consequent loss of valuable time. Because of the possibility of reproducing the recording with almost no time lag, the monitoring can take place from the reproducing channel, giving the recording engineer the opportunity to check continuously on the quality of the recorded material. Machines of this kind, of course, would have to be suitably designed for motion picture requirements.

Another advantage of magnetic recording is that it is not in the least subject to mechanical vibration or temperature changes. This permits the unit to be used for recording from a moving truck, train, or airplane, under extreme climatic conditions.

COMBINATION TAPE AND DISK RECORDER

A combination tape and disk recorder is one of the latest developments in the sound-recording field. The tape recording unit of the combination tape and disk

recorder shown in Fig. 10 has a recording capacity of one minute. From experience, it has been found that this recording capacity is a sufficiently good compromise to suit the requirements of a training vehicle. For disk recording, a 12-inch, 78-rpm turntable is provided, offering a maximum of four minutes of recording time on one face of the disk. This turntable is equipped with the crystal cutter previously mentioned, and with a permanent-point pick-up having a needle pressure of approximately one ounce. The disk and the tape recorders have approximately the same frequency response, and therefore recordings made on either disk or tape sound much the same.

This combination machine may be used like any other disk recorder. In addition to its ability to record and reproduce any program reaching its microphone, it is capable also of reproducing commercial pressings.

Either the disk part or the tape part of the machine can be used separately, although both can not be used simultaneously except in the sense that a tape

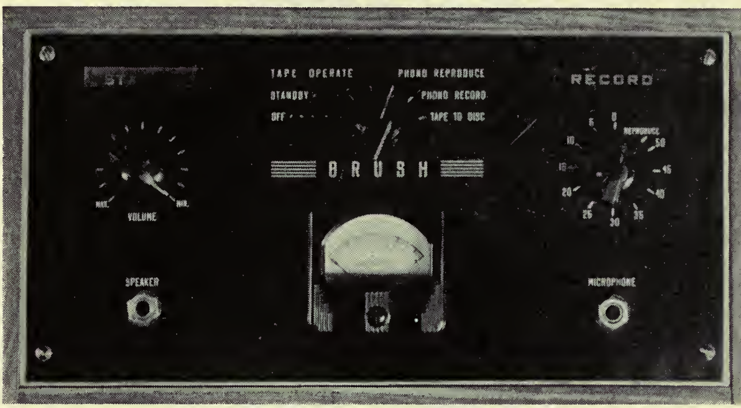


FIG. 12. Control board of combination unit.

recording can be re-recorded on to a disk. This feature allows practicing a selection on the tape recorder until it is judged good, and then re-recording it on the disk as a permanent record.

Fig. 11 is a diagram of the combination unit. Only one amplifier is used, which functions both as playback and recording amplifier for both disk and tape. Naturally the same microphone and loud speaker are used for both. However, the driving mechanism of the disk and tape machines are separate and work independently.

The complete operation of the combination unit is controlled by one simple master switch on a panel board, as shown in Fig. 12. This master switch has six positions—"off," "standby," "tape recording and reproducing," "disk reproducing," "disk recording," and, finally, "re-recording from tape to disk."

The "standby" position has been provided to keep the amplifier warmed up for instant operation. In the "tape" position of the switch, the tape recording machine is ordinarily in the reproducing position, and will reproduce the program

last recorded on the tape. If it is required to make a new tape recording, it is necessary only to turn the time-control knob on the control panel, at which time the machine will be connected in the tape recording position, and will continue in this position for the full time capacity of the tape. At the expiration of this time, the tape machine will automatically switch to the reproducing position. During the recording time of the tape, a red light located above the recorder switch indicates that recording is going on. At the same time, so long as any part of the unit is in operation, a green light on the opposite side of the panel indicates that the unit is ready for operation.

Fig. 10, already referred to, shows the complete unit mounted in a fine wooden cabinet. It shows also the turntable arrangement with the cutting and playback arms. The control board can be folded back out of the way so that the machine, when not in use, can be closed completely. This control board can be provided with a lock so that tampering with the machine is impossible.

The amplifier part of the machine consists of two pentode stages driving a single triode output tube to a maximum capacity of 3 watts. The rectifier of this amplifier provides the obliterating and polarizing currents of the tape recorder, and contains all equalization necessary for the different recording and playback processes. The quality of reproduction is quite adequate for most educational applications, but if particularly high requirements are necessary, a machine of this kind could be built to meet them.

Magnetic recording and disk recording are really good companions, because magnetic recording stands for everything having to do with training, and disk recording for making permanent records. The combination of the two doubtlessly opens new possibilities for further engineering work in the sound-recording field.

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CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

British Journal of Photography

87 (August 30, 1940), No. 4191

Progress in Colour (pp. 419–420)

87 (September 6, 1940), No. 4192

Progress in Colour (pp. 433–435)

Communications

20 (September, 1940), No. 9

Continuous Wave Interference with Television Reception (pp. 5–7, 14, 16–18) — C. N. Smyth

Educational Screen

19 (September, 1940), No. 7

Motion Pictures—Not for Theaters (pp. 286–289), Pt. 19 — A. E. Krows

Electronics

13 (September, 1940), No. 9

New Studios for CBS (pp. 23–25)

Recent Improvements in Recording (pp. 33–35, 79–81) — C. J. Lebel

Motion Picture Herald

140 (September 28, 1940), No. 13

A Remembering of 1915 (pp. 20–22) — T. Ramsaye

Story of Dollars and Names and How the Grosses Grew (pp. 44, 46)

Sentimental Journey Among the Yesterdays of Hollywood (pp. 77–78) — A. Cohn

Developing a Theater for the Motion Picture (pp. 107–110) — G. Schutz

Motion Picture Herald (Better Theaters Section)

140 (September 21, 1940), No. 12

What Your Projectors Should Have to Do Their Job Today (pp. 8–9, 44–45) — F. H. Richardson

Light-Emitting Decoration for Theaters (pp. 19–23) — C. M. Cutler and H. J. Chanon

Photo Technique

2 (October, 1940), No. 10

It's a Small World in Hollywood (pp. 37–41) — W. V. Draper

1941 FALL CONVENTION AT HOLLYWOOD

OCTOBER 21-25, 1940

As the Hollywood Convention will barely have ended by the time this issue of the JOURNAL will have gone to press, the account of the "Highlights of the Convention" and the detailed papers' program will be published in the December issue.

ABSTRACTS OF PAPERS OF THE FALL CONVENTION

The following are abstracts of papers of the Fall Convention received too late for inclusion in the preceding issue of the Journal.

Scene-Slating Attachment for Motion Picture Cameras; F. C. GILBERT, Paramount Pictures, Inc., Hollywood, Calif.

The anticipated reduction of film markets attendant upon disturbances in Europe caused many studios to reëxamine production routines and practices with a view to reducing costs without impairing quality.

A routine, in widespread use in much the same manner, which gave promise of cost saving was that of marking "takes," at time of photographing, for ready identification through subsequent stages of picture production. The process of so marking film is referred to, within the studios generally, as "slating."

Analysis of the shortcomings of the slating method employed by our studio led to the development of a slating attachment mounted upon the camera blimp or iris rods and operated by the assistant cameraman.

The design requirements formulated and the manner and degree of compliance embodied in the device now in production use are described.

Report of the Committee on Exchange Practice; G. R. GIROUX, *Chairman.*

A review of visits to various exchanges investigating the handling of film from the laboratories to the exchanges and from the exchanges to theaters and return.

Methods of inspection, types of shipping cases used, and handling of film by exchange and delivery personnel were studied and are covered in detail in the report, with suggestions as to improvements which can result in improved screen image and longer print life.

American Standards and Their Place in the Motion Picture Industry; J. W. McNAIR, American Standards Association, New York, N. Y.

The American Standards Association is a federation of trade associations, technical societies, and departments of the Federal Government. It was organized in 1918 as a result of the country's experience during the World War, and has since served as the national clearing house for standards. Some 400 American

Standards have been approved to date in a wide variety of industrial fields and in the field of industrial and public safety.

These standards are developed by strictly democratic methods, based upon the principle that every group having a substantial interest in a problem has a right to a voice in its development. More than 600 organizations are at present taking part in the work through 2987 representatives serving on ASA technical committees.

Some years ago at the request of the Society of Motion Picture Engineers, the American Standards Association organized a Committee on Motion Picture Standards. This might be said to be the beginning of national standardization in the photographic field. The committee brought together, under the sponsorship of the SMPE, the Academy of Motion Picture Arts and Sciences, the Acoustical Society of America, and a wide circle of scientific, engineering, and commercial groups interested in cinematography. Some of the standards approved by the ASA through the coöperative work of these many groups have become world-wide.

There are 32 standards and recommended practices now before the ASA for approval as a result of long and arduous work by the motion picture Sectional Committee. These deal with terminology, dimensions, *etc.*, of film and equipment, and with various principles and practices in common use throughout the motion picture industry.

The association is also very actively engaged in the development of national standards for photography. A draft standard for determining photographic speeds of certain types of negative materials will probably be published in a few weeks for trial and criticism.

An Improved Mixer Potentiometer; K. B. LAMBERT, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

The use of conventional mixing potentiometers with rotary manual motion is difficult and inconvenient for re-recording, multiple-channel music recording, or multiple-microphone radio broadcasting. A mixer control having linear motion and other mechanical and electrical advantages, developed primarily for re-recording at MGM Studios, is described. With this apparatus, one operator can control five to eight mixer positions and simultaneously adjust the necessary variable equalizers.

The Photographic Aspects of Television Operations; H. R. LUBCKE, Don Lee Broadcasting System, Los Angeles, Calif.

Television utilizes certain elements of operative photography. In live-subject presentations these include composition, focus, contrast range, intra-image contrast of one object from another, dolly shots, panning, and certain aspects of lighting.

In television, operative maneuvers must be quickly and smoothly executed. The camera in question may be supplying the outgoing image at the time in question, or, if not, it should rapidly be made available for change in camera angle on the program.

The equipment and technic evolved at *W6XAO* to meet these requirements during several years of telecasting is described.

Monochromatic Variable-Density Recording System; O. L. DUPY and J. K. HILLIARD, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

This work was undertaken to determine the benefits of a true monochromatic optical system for variable-density recording in the ultraviolet region. A full quartz optical system consisting of both spherical and cylindrical lenses was used, having a reduction of 10–1 from the light-valve spacing. The reduction in lens distortion and improvement in general image quality is reported along with intermodulation tests on the system, which uses an automatic air-controlled mercury-vapor lamp system.

Recommended Theater Acoustics by the Theater Sound Standardization Committee of the Research Council of the Academy of Motion Picture Arts and Sciences; J. K. HILLIARD, *Chairman.*

A summary of information on recommended theater acoustics collected by this Committee from theater service organizations, architects, equipment manufacturers, and studio personnel.

By combining all the information from these organizations it is now possible to recommend a unified opinion on methods of theater construction which will materially aid in the reproduction of sound pictures in theaters.

STANDARDS COMMITTEE

After initial approval by the Committee in meeting, a letter ballot was recently taken on the following projects:

(1) Rescinding the current SMPE recommended practice for lantern slide dimensions, as published in the March, 1938, issue of the JOURNAL, p. 255.

(2) Adoption of the following recommended practice: "The brightness at the center of a screen for viewing motion pictures shall be 10^{+4}_{-1} foot-lamberts, with no film in the gate." (This is to supersede the original recommended practice published in the March, 1938, issue of the JOURNAL on page 257.)

(3) Adoption as an SMPE recommended practice of the "Research Council Industry Practice for Release Print Sound Track Specifications" as published in the Technical Bulletin of the Research Council of the Academy of Motion Picture Arts and Sciences, dated June 19, 1940.

The letter ballots have indicated approval of these three projects, and publication of the fact is made hereby. If within sixty days of publication of this issue of the JOURNAL, no objections to these proposals arise from the industry, they will be transmitted to the Board of Governors of the Society for validation as SMPE recommended practices.

S. M. P. E. TEST-FILMS

These films have been prepared under the supervision of the Projection Practice Committee of the Society of Motion Picture Engineers, and are designed to be used in theaters, review rooms, exchanges, laboratories, factories, and the like for testing the performance of projectors.

Only complete reels, as described below, are available (no short sections or single frequencies). The prices given include shipping charges to all points within the United States; shipping charges to other countries are additional.

35-Mm. Visual Film

Approximately 500 feet long, consisting of special targets with the aid of which travel-ghost, marginal and radial lens aberrations, definition, picture jump, and film weave may be detected and corrected.

Price $37.50 each.

16-Mm. Sound-Film

Approximately 400 feet long, consisting of recordings of several speaking voices, piano, and orchestra; buzz-track; fixed frequencies for focusing sound optical system; fixed frequencies at constant level, for determining reproducer characteristics, frequency range, flutter, sound-track adjustment, 60- or 96-cycle modulation, etc.

The recorded frequency range of the voice and music extends to 6000 cps.; the constant-amplitude frequencies are in 11 steps from 50 cps. to 6000 cps.

Price $25.00 each.

16-Mm. Visual Film

An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 225 feet long.

Price $25.00 each.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXXV **December, 1940**

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OF THE SOCIETY OF
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WELCOME BY THE PRESIDENT*

TO THE

1940 FALL CONVENTION AT HOLLYWOOD

OCTOBER 21–25, 1940

With the arrival of December thirty-first this year, I shall have closed my two-year term of office as your President. It is with mingled feelings of relief and regret that I shall turn over to my successor the honor and the responsibilities of the Presidency of the Society of Motion Picture Engineers. I can say to him that this job is not a sinecure. Any man who takes seriously his responsibilities as the chief officer of our Society is going to work long and hard during his two years of incumbency. Our constitution and by-laws wisely provide for a decentralization of executive functions and it has been my good fortune and pleasure to have as fellow officers and governors of this Society, some of the finest, most conscientious and hard-working associates that any chief executive could wish for. If the SMPE has made progress during my administration, it is because of the fine support I have had from these men.

It seems fitting that I should give to you an accounting of my stewardship during the time I have served as your President. The future will tell whether our activities have been truly beneficial and worth while or otherwise, but the record will show the actions taken.

As a first endeavor, I have striven to promote a closer, friendlier and more coöperative understanding between our Society and other technical bodies, particularly the Research Council of the Academy of Motion Picture Arts and Sciences. As individuals we like to talk about the beauties of democracy and extol the benefits of coöperation, but I find that, too often, we prefer each to go his own way, and fail to practice what we preach. In the officers of the Research Council and in our own officers and governors, particularly those of the Pacific Coast, I found persons who felt as I did about these matters. In

* Presented at the 1940 Fall Meeting at Hollywood, Calif.

the past two years, therefore, I can report that much progress has been made toward this better understanding and our standardizing activities are now carried on in a truly coöperative manner.

Before proceeding further with this report, it might be well to take cognizance of the growth in membership and resources of our Society. Early in this administration, the grade of Fellow was made an honorary grade rather than one for which an Active Member could apply. This action was in keeping with the meaning of the grade of Fellow in other technical societies. At that time we adjusted the dues of members by raising the dues of Associates from \$6 to \$7.50 per year, the Actives from \$10 to \$15 per year and reducing the Fellows (whose voting and office holding privileges were at the same time bestowed upon Active Members) to the same rate as Actives, namely, from \$20 per year to \$15 per year. We had no assurances what this would do in the matter of losing members or of losing total revenue. I am happy to report that, while we lost some few members through this action, we have increased our total membership from 1319 on January 1, 1939, to 1368 as of July 1, 1940—this despite greatly distressing conditions throughout the world. Our bank reserve funds have increased from \$21,353 on January 1, 1939, to \$27,898 on July 1, 1940. Our Sustaining Members have held or increased their contributions to the Society and during the year 1940 we have added 5 new sustaining members, making a total of 22.

As another accomplishment of this administration, I should like to mention a change in policy whereby our Society will hold every third semi-annual meeting in Hollywood instead of every fourth such meeting as heretofore. In this way the results of annual elections and the presentation of the Society's Annual Progress and JOURNAL Awards will be made alternately in the East and in Hollywood. This will certainly promote more intersectional interest in the affairs of our Society than was possible under our former arrangements.

In past years, so-called "Standards" covering apparatus and other articles used in our industry have emanated from both our Society and from the Research Council. These "Standards" were sometimes in conflict with similar "Standards" set up by the other body or in conflict with recognized practices in large and important parts of our industry. Realizing that for certain elements of our industry a degree of standardization might be desirable even without prior consulation and agreement with any other body, our Society and Research Council have agreed that hereafter such unilateral standards shall be desig-

nated "Recommended Practices." Only those standardizations on which both organizations have consulted, agreed, and cleared through the American Standards Association shall be called "Standards" and be so labeled in our respective bulletins or other publications. By this sensible arrangement, we shall remove causes of friction and uncertainty in our industry and make true progress toward real standards.

In past years, we have sometimes found it difficult to amend our by-laws as needed, due to difficulties in obtaining a quorum at our semi-annual meetings. An amendment to these by-laws was adopted by our Society some eighteen months ago, whereby proposed amendments must be published in our JOURNAL in the issue next preceding any semi-annual meeting. The time and place of the business session are also published. If we are unable to obtain a quorum at such time, the Board of Governors of the Society is then empowered to adopt or reject the amendments as proposed, and such action is final. In this manner, the business of our Society can be expedited and kept up to date while retaining full control in the hands of the active membership at large.

Another amendment of importance in speeding up Society business is that pertaining to the admission of members. Formerly applications for Active Membership were submitted first to the Society headquarters in New York, then to the Admissions Committee who communicated with the applicant's references. When these replies were received (which often took several weeks and even months) the complete report was submitted by the Admissions Committee to the members of the Board of Governors by mail, for their vote. Here, again, much time was lost and many an applicant has waited six months or more before he learned of his acceptance or rejection. Our new procedure places upon the applicant the responsibility for getting the recommendations of his references and the application goes either to the New York headquarters of the Society for persons residing in the East, or to the Hollywood office in cases where the applicant resides west of the Rocky Mountains. We now have two Admissions Committees who pass immediately upon these applications in the East or in the West and the applicant now receives his answer in a few days, rather than in a few months.

It is the belief of our Society that repeated, unbroken terms of office held by any one individual, no matter how competent, are not good for our Society. To that end, the by-laws stipulate that the

President may not immediately succeed himself in that office. Through amendments to our by-laws adopted during my term of office, all committee appointments run only for the term of office of the appointing officer unless sooner terminated by him, but in no case may the chairman of any committee serve as such for more than two consecutive terms.

Consideration was given further to limiting the terms of office of the other Society Officers and Governors but it was felt that this purpose could best be accomplished by a change in our method of nominating such Officers and Governors. By a change in our by-laws, this function was taken from the Board of Governors and placed in the hands of a nominating committee, appointed by your President, four of the nine members of which committee are to be chosen from non-office holding members of our Society, two others being Past-Presidents, and the other three, members of the Board not up for re-election. This removes any tendency toward self-perpetuation in office and insures a democratic process in the conduct of our Society's affairs.

In the past, there has been some overlapping of jurisdiction among the officers of the Society and some uncertainty as to proper fields of activity. During the past six months, your Board of Governors has given attention to this problem with the result that just yesterday at its meeting here, definite and detailed definitions were set down for the guidance of each officer in the conduct of the duties of his office. At a later date, we expect to set up similar working rules for the various standing committee chairmen.

I might go on in detail recounting the good work of the various committees of our Society through and by whom the principal work of the Society is done. This information, however, will be covered more adequately than I could do by the official reports of these committees and the reports of the Vice-Presidents whom you have already heard or soon will hear. I shall, therefore, close this accounting of my stewardship with a word of deep appreciation to all those officers and members who have worked so loyally for the success of our Society during my term of office. Of those who shall continue in office, I bespeak your continued efforts in support of our new President. With those others, who, like myself, are laying down the responsibilities of office at the close of this year 1940, I join in pledging our continuing efforts toward the world-wide growth and influence of our great Society of Motion Picture Engineers.

E. ALLAN WILLIFORD, *President*

PROCEEDINGS OF THE SEMI-ANNUAL BANQUET

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL

OCTOBER 23, 1940

Nearly 350 members and guests of the Society assembled at the 47th Semi-Annual Banquet held at the Hollywood-Roosevelt Hotel, Hollywood, Calif., on October 23rd. Guests at the Speakers' table were: President E. A. Williford; the Hon. Fletcher Bowron, Mayor of the City of Los Angeles; Mrs. Fletcher Bowron; Mr. Walt Disney, recipient of the 1940 Progress Medal; Major Nathan Levinson, citationist for Mr. Disney; Mrs. Nathan Levinson; Dr. Edison Pettit, representing Dr. Robert R. McMath, recipient of the 1939 Journal Award; Mrs. Edison Pettit; Dr. J. G. Frayne; Dr. Lee de Forest, Honorary Member-Elect of the Society; Mrs. Lee de Forest; Mr. Earl Theisen, Chairman of the Historical Committee recommending honorary membership for Dr. de Forest; Mrs. Earl Theisen; Mr. Emery Huse, President-Elect of the Society for 1941; Mrs. Emery Huse; Mr. and Mrs. L. L. Ryder; Mr. Rudy Vallee; Mr. and Mrs. Keith Glennin; Mr. James Cagney; Mr. James Frank, Jr.

After introducing those seated at the Speakers' table, President Williford announced the results of the election of Officers and Governors of the Society for 1940, which were as follows:

***President:* EMERY HUSE
***Executive Vice-President:* HERBERT GRIFFIN
***Editorial Vice-President:* ARTHUR C. DOWNES
***Convention Vice-President:* W. C. KUNZMANN
**Secretary:* PAUL J. LARSEN
**Treasurer:* GEORGE FRIEDL, JR.
***Governor:* MAX C. BATSEL
***Governor:* LORIN L. RYDER

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* Term Expires December 31, 1941.
** Term Expires December 31, 1942.

Following this announcement, President Williford gave a brief description of the nature of the Progress and Journal Awards made each year by the Society at the banquet of the Fall Convention, and called upon Major N. Levinson, Chairman of the Progress Award Committee, to announce the recipient of the Award for this year, and to give an account of the work of the recipient forming the basis for the award:

WALT DISNEY

RECIPIENT OF THE SMPE PROGRESS MEDAL

NATHAN LEVINSON

The newspaper comic strip has for a great many years been quite an institution in American life, and it was to be expected that sooner or later it would make its way to the motion picture screen. The purpose of the comic strip has always been to amuse, and since the motion picture has always been a powerful medium of amusement and entertainment, the application of cartoon principles to the motion picture was a logical feature in the development of the motion picture art.

Cartoons were used in motion picture almost from the very beginning, as would be expected from the fact that the motion picture as we all know, is merely a succession of still pictures; and if these still pictures can be made by photographic means, they can be made also by artists using pen and pencil.

There have been many in the history of the motion picture who have been active in the introduction and development of the cartoon, but there is one man who stands head and shoulders above them all, in that he has not only produced cartoons, but has developed them far beyond what ordinary persons like ourselves could imagine only a few years ago. To make a cartoon, and to make a real living thing out of it; to develop it into lovely colored bits of fantasy and story; to make the characters of legend and fairy tales come to life, and walk and talk, and arouse in us emotions equal to those we experience when viewing pictures of live human actors—it is almost too much to believe.

I am sure, after these remarks, the name of the person to whom I refer, who has this year been awarded the Progress Medal of the

Society of Motion Picture Engineers, is still a deep secret. But, just between us, it's Walt Disney—the man whose "Mickey Mouse" and "Minnie Mouse" are important matters to all the children of America

WALT DISNEY

and to millions of children in other countries, and add immeasurably to the pleasure and happiness also of sophisticated grown-ups. The Disney *Silly Symphonies*, those lovely colored fantasies, are, without

doubt, America's finest contribution to the world's folklore. Legend and fairy tales have come to life and have become part of our own lives.

But about Walt Disney himself: He was born in Chicago in 1901, of Irish-Canadian and German-American descent. His father was a contractor and builder in Chicago for twenty years. Later the family moved to Marceline, Missouri, where Walt had his early schooling and went into the business of selling newspapers and indulging in amateur theatricals. On amateur nights in neighborhood theaters, he often gave impersonations of The Great Chaplin, for which he sometimes won prizes amounting to as much as $2. Later in Chicago he tried a Dutch comedian act, which ended his stage career.

But the thing he always liked to do best was to draw pictures. He never knew why, since no one else in the Disney family was at all artistically inclined. At the McKinley High School in Chicago, Walt divided his attention between drawing and photography, doing illustrations for the school paper, and at the same time trying to make motion pictures with a camera and projector he had bought. Not content with going to school in the daytime, he also went to night school at the Academy of Fine Arts where he studied cartoon drawing under Leroy Gossitt—a member of the old Chicago *Herald* staff.

With school over, he had to find a job. He became a "news butcher," selling peanuts, candy, and popcorn to the passengers on trains between Kansas City and Chicago. But this venture did not last very long; it was not very profitable and young Disney—he was fifteen at the time—had to eat.

In 1918, he had a brief job with the Chicago Postoffice as a downtown letter carrier in the daytime and a route collector at night. The great war, at about that time, became really serious with America, and Disney felt that he ought to enlist. Turned down by the Army, the Navy, and the Canadian Enlistment Office on account of his age, Walt began to feel as if he were too young for anything. He finally was able to join the American Red Cross as a chauffeur and was sent overseas. He had the distinction of driving one of the most unusual ambulances in France—for with all the excitement of the war, he had not forgotten his drawing. His vehicle of mercy was covered from stem to stern with works of art—no wartime camouflage—but original Disney sketches.

With the war ended and with Disney's return, he did not want to go back to school, but felt that he ought to do something practical, con-

structive. He took a job with an advertising concern in Kansas City, doing sketching and free lance work designing letterheads and theater slides, when one day he noticed an advertisement of a slide company in Kansas City who wanted a cartoonist. This was the beginning of his cartoon work, using the old cut-out method of animation, joining arms and legs together with pins and moving them under the camera. His home experiments led to the making of a short reeel of local Kansas City incidents, which he sold to the owner of three large local theaters at 30 cents a foot. *Mickey Mouse* and *Silly Symphonies* today cost well over $25 a foot. His home experiments continued and his next production was a short subject called "Little Red Ridinghood." He left his job with the slide company and formed his own company, to produce modernized fairy tales.

To recite all the vicissitudes with which he had to contend in starting his company, seeing it fail, and trying to regain his financial backing, would take hours. Walt had by this time married Lillian Bounds, who had been one of his assistants in operating the camera in producing the *Alice* cartoons. Many attempts were made to interest producers and exhibitors in his early cartoons, *Alice, Oswald the Rabbit,* and several others, until one day the thought occurred to him to feature a cute little mouse that used to crawl round his desk when he was working with the slide company in Kansas City. "Mickey" he called the mouse, and he worked enthusiastically on his first *Mickey Mouse* scenario. Mrs. Disney helped with suggestions and encouragement. His "Mickey" had to have a sweetheart, of course—they called her "Minnie Mouse," and thus was born the first *Mickey Mouse* cartoon, which was later to take the world by storm. Several *Oswald* subjects were also in work for a New York company, but they worked on the *Mickey Mouse* story at the same time, in their garage. When completed, it seemed rather disappointing, but Walt sent it off to New York. No one in the East seemed to want Mickey Mouse. *The Jazz Singer* had just been released with sound, and the first Mickey Mouse cartoon was silent. Who could have thought at that time of such a thing as a cartoon synchronized with sound.

In spite of its failure to sell, Disney went to work on a second Mickey Mouse, and planned a third, which he sent to New York to be synchronized with sound. The third Mickey Mouse *Steamboat Willie,* was the first to be shown publicly.

Despite a number of setbacks and dissension in the ranks, Disney kept at work. He developed his own system of synchronization,

formed his own company for producing and distributing *Mickey Mouse* pictures independently, and the rest of the story everyone knows. Mickey Mouse got a great welcome from the public and the Disney business grew. His company expanded, and although experience artists were hired, Walt soon felt that it was wiser to train his own men to the Disney Way of thinking and doing. As the staff grew, there were changes; whereas five years ago, the Disney organization consisted of twenty-two people, there are now more than one thousand employees, with a research department, music librarians, and many other adjuncts. Improvements in the development of the cartoons, in the technic of producing the individual still pictures, in photographing them, all these followed one after the other. But aside from the technical developments of cartoon making for which Disney was responsible, Walt still remained the artist. His Silly Symphonies, the first of which was the *Skeleton Dance,* were based on musical themes without special central characters, producing effects of atmosphere and emotional reaction rather than attempting to develop any particular story lines. So the Disney developments kept on, proceeding to the production of complete feature-length stories in cartoon form—*Snow White and the Seven Dwarfs* and *Pinnochio.* In addition to the considerations upon which the award has been made, I was privileged to see the forthcoming production *Fantasia* last Saturday night at the Disney Studio. This latest Disney production is beyond description in language at my command. Speaking from technical angles, more has been done with color, sound, and ideas in *Fantasia* than I ever dreamed possible. I can only say that the production is a magnificent technical achievement, and I am sure Walt will again be acclaimed for the wonderful and daring advancement of this art.

Walt has always been a creator—a creator of personalities. Mickey Mouse is a real person, on the screen and in the minds and hearts of the hundreds of millions who know and love him. He has a distinct personality, along with Minnie Mouse, Pluto, Donald Duck, and all the rest. The Silly Symphonies roam far afield in the land of fantasy. In addition to the artistic and human interest in his productions, the value of the technologic developments for which Walt has been responsible cannot be over-estimated. It is on the basis of all of this that I have said, and much more that could well be said, that I have the pleasure of informing you, Mr. President, that the Progress Award Committee and the Society of Motion Picturre Engineers

nominated Walt Disney for the SMPE Progress Medal for 1940.

At the conclusion of Major Levinson's address, President Williford presented the Progress Medal to Mr. Disney with the citation:

TO WALT DISNEY:

In recognition of his major contributions to Motion Picture technology, in the establishment of correspondingly advanced laboratory facilities and methods in the photography and sound recording of feature and short cartoon films, and in the evolution of outstandingly adequate technic in color and black-and-white cartoon film production.

Following the citation by President Williford and the presentation of the medal, Mr. Disney briefly thanked the Officers of the Board of Governors and members of the Society for the honor thus bestowed upon him.

President Williford next called upon Dr. J. G. Frayne, Chairman of the Journal Award Committee, to name the recipient of the Journal Award for 1939, and to present an historical account on the basis of which the award has been granted. Dr. Frayne spoke as follows:

ROBERT R. McMATH

RECIPIENT OF THE SMPE JOURNAL AWARD

J. G. FRAYNE

In selecting the paper for the Annual Journal Award of the Society for the year 1939, the Journal Award Committee has chosen a paper that does not deal with any of the ordinary mundane subjects confronting the motion picture industry, but instead, deals entirely with celestial matters. The subject of the paper is *The Surface of the Nearest Star* and the author is an astronomer rather than a motion picture engineer. The winning paper and its associated motion picture films depict by extension of motion picture technic to the spectroheliograph—a science known as spectroheliokinematography—the storms that whirl around the sun spots of our nearest star . . . . the sun, and the intricate motions of the mighty gaseous prominences that rise for thousands of miles above the solar surface, and move and disintegrate with speeds ranging from few to several hundred miles per second.

These pictures are unique because no other installation exists at present for similar motion picture records of solar phenomena. The films described in the paper show scenes of unexampled grandeur and

R. R. McMATH

make us realize that the surface of our nearest star has an unending maelstrom of motions due to titanic forces, the precise nature of which cannot as yet be regarded as completely explained.

The author of this paper is Dr. Robert R. McMath, Chairman of the Board of the Motors Metal Manufacturing Company of Detroit. He was born in Detroit, Michigan, in 1890 and graduated from the University of Michigan with the degree of Bachelor of Civil Engineering in 1913. Following his graduation he occupied several engineering positions with structural engineering concerns. During the World War he served in the aeronautics department of the Air Service, entering as a Second Lieutenant and being discharged into the Reserve Corps as a Major. He was appointed General Manager of the Motors Metal Manufacturing Company in 1922 and has been identified with that company ever since, having been Chairman of the Board since 1939. Since 1928 he has served as a Director of the McMath-Hulbert Observatory of the University of Michigan. In 1929–30 he found time to design and build the $10^1/_2$-in. telescope and its dome and in 1935–36 he designed and built the 50-in. telescope of the McMath-Hulbert Observatory of the University of Michigan.

From 1929 to the present he has been Honorary Curator of Observatories of the University of Michigan. In 1933 he received the honorary degree of Master of Arts of the University of Michigan and in the same year received the John Price Wetherill Medal of the Franklin Institute at Philadelphia. In 1936 he received the Rittenhouse Medal and honorary life membership of the Rittenhouse Astronomical Society of Philadelphia. In 1938 he received the honorary degree of Doctor of Science from Wayne University, Detroit, Michigan.

Dr. McMath belongs to numerous technical and scientific societies including TBΠ, ΣΞ; American Society of Civil Engineers; Fellow, Royal Astronomical Society, London, England; International Astronomical Union, Paris, France; American Astronomical Society; Optical Society of America; Advisory Committee, 200-Inch Astrophysical Project, California Institute of Technology; and member of the American Society of Motion Picture Engineers.

He is author of numerous publications dealing with such subjects as the McMath-Hulbert Telechron Driving Clock; Some New Methods in Astronomical Photography with Application to Moving Pictures of Celestial Objects; numerous papers in collaboration with Dr. Edison Pettit on spectroheliograph studies of solar prominences.

He is a much sought-after lecturer and has lectured before such learned societies as the American Philosophical Society, the National Academy of Science, the American Astronomical Society, the Royal Astronomical Society, and the British Association for the Advance-

ment of Science, on various features of his activities at the McMath-Hulbert Observatory.

Mr.President, the Committee feels that it is a rare honor for the Society to have such a distinguished gentleman and scholar contribute to the JOURNAL, and it feels confident that the selection of Dr. McMath's paper for the Journal Award will meet with the unanimous approbation of the Society.

At the conclusion of Dr. Frayne's address, President Williford presented the Journal Award certificate to Dr. Edison Pettit of the Mt. Wilson Observatory, representing Dr. McMath, who, unfortunately, was unable to attend the banquet. Dr. Pettit responded with appropriate words of thanks for Dr. McMath.

At the meeting of the Board of Governors of the Society, held on October 20th, Dr. Lee de Forest, inventor of the audion and responsible for numerous advances in motion picture technology, was proposed and approved for honorary membership in the Society.

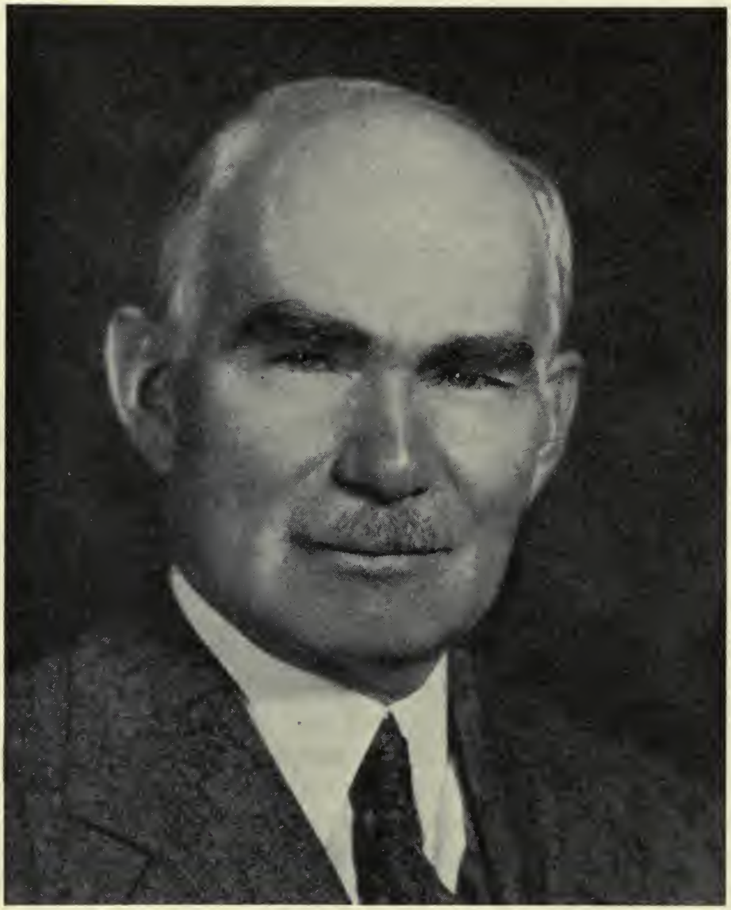
At the open business meeting of the Society held during the technical session on the evening of October 22nd, the proposal was duly ratified and validated. President Williford therefore, at the conclusion of Dr. Pettit's brief address, called upon Mr. Earl Theisen, Chairman of the Historical Committee initiating the proposal, to present an account of the work of Dr. de Forest leading up to the conferring of honorary membership upon him. Mr. Theisen spoke as follows:

THE WORK OF LEE de FOREST

Few names loom so large in the history of the development of the electronic arts and their application to the talking picture as does that of Lee de Forest.

Lee de Forest invented the audion detector tube which with the electronic amplifier opened a boundless field for scientific research. Through the medium of this new tool many a forgotten dream of the early inventor was brought to realization, such as long distance telephony, the scanning disk of Nipkow and Campbell-Swinton's cathode-scanning beam.

This prolific inventor and pioneer was born at Council Bluffs, Iowa, in 1873. He is the son of Dr. Henry Swift de Forest, a Congregationalist minister, who moved with his family to Talledega, Alabama, in 1879 when he became the first president of Talledega College.



LEE DE FOREST

Following preparatory work at Mt. Hermon Boys' School in Massachusetts, Lee de Forest followed his father to Yale University where he entered the Sheffield Scientific School. Following his graduation in 1896 he continued with graduate study. During this period he

enlisted in the Yale Battery, although he saw no outside service, and completed his studies, being granted his Ph.D. in 1899.

Dr. de Forest entered the service of the Western Electric Company in Chicago immediately after completing his work at Yale and was assigned to the dynamo works and the telephone laboratory of that organization. Thus his commercial career began in the field of electrical communication. The following year he left the employ of Western Electric to engage in private research in Milwaukee on the self-restoring detector. At this time the European wireless systems, led by the Marconi group, were using the coherer for detection. With the reception of each signal the filings grouped together and it was necessary to decohere them mechanically by tapping the tube. This slowed down the permissible speed of transmission. The use of the coherer together with the Morse inker and a relay was the reception method in general use. In Milwaukee de Forest began his research on the electrolytic detector which in itself, being self-restoring, was faster than the coherer, but in allowing the use of a telephone receiver for the audible reception of signals, greatly improved wireless reception. Using this method it was possible for an operator to distinguish audibly between signals and "static" and also between several sets of signals being received simultaneously.

Dr. de Forest returned from Milwaukee to become assistant editor of the *Western Electrician* during which time he carried on independent wireless research at the Armour Institute. In the summer of 1901 the American de Forest Wireless Telegraph Company was organized in Jersey City to exploit the de Forest equipment formed around the electrolytic detector. The next five years were spent on the development of this commercial equipment, vessels of the Clyde and Mallory steamship lines being equipped. The U. S. Navy also used de Forest equipment almost exclusively. The operations of the Company were further extended by the demonstration for the British General Postoffice of the first successful transmission across the Irish Sea, which took place between Holyhead, Wales, and Howth, near Dublin.

It was during this test that a loop antenna was used for the first time. In U. S. patent No. 827,523 such a loop was disclosed not only in the general form but also that in which the two sides were separated by one-half wavelength. In a further specification filed in May, 1904, the use of a directional loop mounted on a vertical axis is shown. This freedom of rotation about a vertical axis is the basis of the radio

direction finders of the present day. In patent No. 748,597, filed in December, 1902, de Forest described the use of a vertical antenna at the focal point of a reflector made up of parallel vertical rods arranged on the periphery of a parabola.

In the development of his system the inventor from the first used higher transmitting frequencies than did the other organizations. The directional antenna, the reflector antenna, and such other discoveries so preceded their adoption on a commercial scale that the patents expired before such use.

On January 20, 1905, Captain Lionel James described before the Society of Arts in London the use of the de Forest equipment for the reporting of the Russo-Japanese naval engagement at Port Arthur by the London *Times.* A station established aboard the *Haimun* transmitted Captain James' reports to the shore station at Wei-hai-wei from which they were forwarded to London by cable. This was the first application of the new wireless developments to news reporting.

Prior to the reorganization of the American de Forest Wireless Telegraph Company as the United Wireless Telegraph Company in 1906, the inventor had obtained more than sixty U. S. patents on wireless equipment and design. On July 1, 1905, de Forest successfully transmitted to a moving train of the Chicago and Alton R. R. running between St. Louis and Chicago. The United Wireless Company was subsequently purchased by the American Marconi Wireless Telegraph Company.

Due to the unwillingness of the United organization to provide the inventor with necessary funds to continue his audion research, de Forest left this Company in 1906. It was during this year that the first audion was made in the inventor's laboratory in the old Parker Building at 19th Street and 4th Avenue, New York City. The following spring the first actual transmission of music by wireless took place. This was from the Parker Building, the sound source being inductor alternators. During the summer twenty-six radio telephone transmitters for Admiral Evans' fleet were tested by the transmission of phonograph records. During this summer also the International Yacht Races on the Great Lakes were reported by radio telephone, the announcements being supplemented by phonograph records.

As early as 1909 de Forest attempted to market radio equipment for the amateur, a display being set up for this purpose in the Metropolitan Life Tower in New York. In January of that year the first

radio broadcast took place when, using an arc transmitter, the inventor broadcast the voices of Caruso and other Metropolitan Opera stars from the stage of the "Met." This program was received by numerous operators on ships then in New York harbor.

Shortly after this the inventor went to Palo Alto, Calif., where his research was continued. It was there, on August 6, 1912, that the feed-back oscillator circuit was discovered by de Forest. Although Alexander Meissner, a German inventor, Dr. Irving Langmuir of the General Electric Company, and Major Edwin H. Armstrong were other claimants to this discovery, de Forest's priority was upheld by the District Court of Appeals in Washington, D. C., on May 5, 1924, after a seven-year legal battle. The decision of the court was based largely upon written laboratory notes by de Forest who had always kept careful and systematic records of his experimental work.

Dr. de Forest established the first regular broadcasting at his laboratory at High Bridge, N. Y., during the summer of 1916, the programs being sent out on a regular schedule. These programs consisted of Columbia phonograph records, credit being given in the announcements to the Columbia Company. During the presidential campaign in the fall of that year the election returns were broadcast by this station in coöperation with the New York *American*. The establishment of this regular broadcasting service preceded by four years the operation of station *KDKA* of the Westinghouse Electric and Manufacturing Co., which began its service in 1920. Dr. de Forest initiated the first broadcasting on the Pacific Coast when this was begun by a station located in the California Theater in San Francisco in May of 1920. During these years of intensive research and development more than one hundred and fifty U. S. and foreign patents were granted the inventor, among these being several basic in their claims which dominate the radio art today.

Dr. de Forest, who is a Fellow of the American Institute of Electrical Engineers and of the Institute of Radio Engineers, is an active member of the Society of Motion Picture Engineers. Many honors have been bestowed upon him for his inventive genius. He has been awarded Gold Medals at the World's Exposition at St. Louis in 1904, and at the Panama Pacific Exposition in San Francisco in 1915. In 1920 he was granted the Cross of the Legion of Honor by France, and in 1923 he was given the Prix San Tour by the Academy of Sciences and the Institute of France. He has received the honorary degree of D.Sc., from the University of Syracuse in 1919 and from his alma

mater, Yale University, in 1926. In 1922 he was given the Medal of Honor of the Institute of Radio Engineers, in 1923 the Elliot Creson Gold Medal of the Franklin Institute, and in 1930 the John Scott Medal of the city of Philadelphia. He was made an Honorary Member of the Yale Chapter of Sigma Xi in 1929, and a member of the Aurelian Honorary Society of Yale in 1930. He is also a member of TBΠ.

Lee de Forest's work in the field of electrical communication has to some extent been influenced by his innate love for music. In his desire to make good music available to more people he has sought to do so by electrical means. That his first broadcast should have been from the Metropolitan Opera House is an indication of this desire, and it is interesting to note that the programs furnished by his broadcasting station at High Bridge consisted of recorded musical numbers.

With the development of broadcasting into the commercial stage, the inventor turned his attention to other fields of exploration. As early as 1913 de Forest had made experiments in recording with the Poulsen electromagnetic wire method. Six years later he began his researches on photographic means of sound recording with the definite purpose of providing a voice for the then silent picture.

In 1919 de Forest experimented with three methods of sound recording: (*a*) the speaking flame, (*b*) the tiny incandescent filament, and (*c*) the glow-tube. The latter soon showed itself to offer the most hope of practical success. He first demonstrated a combination of sound-on-film with picture at his Highbridge Laboratory in the spring of 1921. To quote de Forest: "This early work, when apparently only we two (William Garity and myself) believed there was a commercial future for the talking picture, evidently sank deep within Garity's soul, for today Garity is chief factotem for Walt Disney; possibly because that primitive recording was chiefly suggestive to him of the squeaks of Mickey Mouse."

In 1921 de Forest suggested the use of two separate synchronized negatives, one for the picture, one for the sound, each given its proper development, and each printed successively on a common positive. Lee de Forest first commercially introduced sound-on-film motion pictures to the public on April 15, 1923, at the Rivoli and Rialto theaters, New York.

De Forest filed patent applications in 1923 to 1925 on such practical inventions as (*1*) the use of two or more picture cameras at different angles and focal distances, all synchronized to a common sound-re-

cording camera; (*2*) the blacking out by printing of the otherwise noisy pauses in the positive sound-track; (*3*) the method of dubbing sound recorded in synchronism with a projected picture. Another patent issued during this era covered the camera "blimp" in an acoustically treated studio. Early experience in actual theater presentations led to the joint invention with Louis Reynolds of the now well known "tone control" whereby the operator or a monitor in the auditorium itself was enabled to mix the relative values of high and low frequencies to suit best the acoustical characteristics of the theater.

De Forest also took out a patent for an independent volume-control sound-track. Over fifty patents have been issued to de Forest dealing exclusively with motion pictures.

In view of these outstanding contributions to the building of the motion picture, on behalf of the Historical Committee, I wish to present the name of Lee de Forest for Honorary Membership in the Society.

At the conclusion of Mr. Theisen's address, Dr. de Forest responded briefly.

The banquet concluded with dancing and entertainment.

REPORT OF THE COMMITTEE ON THEATER ENGINEERING*

Summary.—*An account of the work of the several sub-committees of the Theater Engineering Committee during the past year. The report of the Sub-Committee on Projection Practice embodies a comprehensive power survey in theaters throughout the country, and interim reports of the Working Committees on Tools and Tolerances, and on Fire Hazards. The report on screen brightness and illumination meters includes an analysis and organization of the entire practical system of photometric nomenclature and conversions.*

The report of the Sub-Committees on Theater Design refers to the projected glossary of terms used in the theater design and discusses the question of staggered seating in theaters. Consideration is given also the proposal to use green instead of red lights for auditorium exit signs.

Prior to 1930 relatively limited attention was paid by the Society to the practical problems of projection, aside from the usual activities of the Standards Committee in establishing dimensional specifications for equipment. In 1930, however, the Board of Governors decided that it was timely, because of the growing complexity and importance of the art of projection, to establish a committee whose function would be to investigate the problems of practical projection, to establish recommendations for the design and layout of projection rooms, and to formulate recommended operating and maintenance procedures. Such a committee was formed under the name of the "Projection Practice Committee," and it has been active continuously, and in a valuable and important way, for ten years. For the past several years consideration has been given by various members of the Board of Governors of the Society, informally and from time to time, to the possibility of enlarging the scope of the Projection Practice Committee so as to include all phases of theater design, aside from the commercial, as well as problems of projection *per se*.

Some phases of theater design had already been considered by the Projection Practice Committee, but it was felt that there were other phases that should be analyzed, and that the Projection Practice

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* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 10, 1940.

Committee, as then constituted, was not fully equipped to handle all such matters.

At the meeting of the Board of Governors on July 13, 1939, it was resolved that the Projection Practice Committee be superseded as of December 31, 1939, by a new committee, to be known as the "Theater Engineering Committee" and which would take over and broaden the work then being conducted by the Projection Practice Committee.

This was accordingly done, and in January, 1940, a chairman was appointed and the personnel of the Committee established. This personnel is given in a later section of this report. The duty of the Theater Engineering Committee is to gather technical and operating facts, digest and analyze these facts, consider equipment and operating methods, and issue from time to time reports covering matters of interest to the exhibitor, architect, and engineer. The activities of the Committee are conducted mainly through two sub-committees. One of these, the Sub-Committee on Projection Practice, continues substantially the activities of the previous Projection Practice Committee, including the study of problems relating specifically to motion picture film, projection equipment, projection room design and construction, motion picture screens, sound-reproducing equipment, and loud speakers, together with the related measurement and test methods.

The Sub-Committee on Theater Design is concerned with those features of design and construction of theaters contributing to better picture quality and entertainment value, including seating arrangements, floor contours, wall construction (from both the acoustic and visual viewpoints), and numerous additional related matters.

Meetings of the two sub-committees are held separately, each month, and each sub-committee has established for itself a number of "Working Committees" to attend to the various details of the work. Widely representative membership has been selected for both sub-committees and it is expected that steady progress in the development and improvement of theater design and operation will result over a period of years from the activities of the Theater Engineering Committee.

The personnels of the main committee and the two sub-committees are as follows:

THEATER ENGINEERING COMMITTEE

ALFRED N. GOLDSMITH, *Chairman*

Projection Practice Sub-Committee

H. RUBIN, *Chairman*

T. C. BARROWS
H. D. BEHR
K. BRENKERT
F. E. CAHILL, JR.
C. C. DASH
A. S. DICKINSON
J. K. ELDERKIN
J. FRANK, JR.
R. R. FRENCH
E. R. GEIB
M. GESSIN
A. GOODMAN
H. GRIFFIN
S. HARRIS
J. HOPKINS
C. HORSTMAN
L. B. ISAAC
P. J. LARSEN
J. H. LITTENBERG
M. HOBART
E. R. MORIN
J. R. PRATER
F. H. RICHARDSON
J. J. SEFING
V. A. WELMAN
R. O. WALKER
H. E. WHITE
A. T. WILLIAMS

Theater Design Sub-Committee

B. SCHLANGER, *Chairman*

F. W. ALEXA
J. S. CLARKE, JR.
D. EBERSON
J. FRANK, JR.
M. M. HARE
M. HOBERT
S. HARRIS
C. HORSTMAN
K. C. MORRICAL
E. R. MORIN
I. L. NIXON
C. C. POTWIN
A. L. POWELL
A. L. RAVEN
R. F. ROSS
E. S. SEELEY
J. J. SEFING

REPORT OF THE PROJECTION PRACTICE SUB-COMMITTEE

Power Survey

A questionnaire has been formulated to secure a cross-section of data in relation to (*1*) the trend in current consumption for the various electrical units used in theaters throughout the country; (2) the total cost of electric current; (*3*) energy consumption charges; and (*4*) the average proportions of power used for projection, air-conditioning, lighting, *etc.*

The Committee felt that about 1600 of these survey reports, representing about 10 per cent of the total number of theaters, should be received before attempting to summarize the data obtained. Up to the present time, 1300 reports have been received. However, some of them will have to be discarded because of incompleteness of the data submitted. The present report on the data received is therefore preliminary, to indicate principally the nature and purposes of the study being conducted by the Working Committee on the Power Survey.

It is expected that a final and complete report will be available at the next Convention of the Society in the Spring of 1941.

Very few industries operate with as great a variety of electrical equipment as is found in motion picture theaters. Motors as small as

$^1/_{20}$ hp are used on ticket machines and motors 300 hp in size have been found operating compressors on refrigeration equipment. Projection rectifiers and motor-generator sets in general use range from 3 to 40 hp. Besides power required for incandescent and neon lighting, and radios, additional power is needed for motors used for many purposes, such as for projection, sound reproduction, ventilation, refrigeration, pumps, oil-burners, rewinders, grinders, ticket machines, flashers, vacuum cleaners, *etc.*

A study of the forms of power available in various sections of the country has been undertaken (Table I), with the result that it has been found that 60-cycle alternating current is the standard for power distribution and is almost universally available. More than 95 per cent of the distributed a-c power for general use is at a frequency of 60 cycles. This does not include railways and certain large industries using 25-cycle supply. A frequency of 50 cycles is used in all of southern California and in the vicinity of Los Angeles, although not in the city proper where the 50-cycle supply has recently been converted to 60 cycles. There are no plans to change to 60 cycles generally in southern California. Forty-cycle power is used to a limited extent in New England, principally in Rumford Falls, Me., and in Palmer Falls and Plattsburg, N. Y. Plattsburg has also 60-cycle power. In and around Buffalo the 25-cycle supply for general distribution has been largely supplemented with 60-cycle power, although the heavy industries remain on 25 cycles. Niagara Falls has switched from 25 to 60 cycles.

A small area in Central New York State, north of Oneonta, is supplied with 25-cycle power, and also Keokuk and Ft. Madison, Iowa, and nearby communities. Around Geneva and Auburn, N. Y., the frequency is $62^1/_2$ cycles.

Certain of the larger cities have direct current available in certain districts, but in practically all these districts 60-cycle alternating current is also available. These cities are Cleveland, Chicago, New York, Baltimore, Detroit, Boston, Kansas City (Mo.), New Orleans, Washington (D. C.), St. Louis, and Cincinnati.

There has been a tendency on the part of the large power companies to standardize on 120 volts for lighting and 208 volts for power service. The power companies in many cases meter the power supply on the primary or high-voltage side of the transformers, whether company-owned or theater-owned transformers are used, this procedure resulting in an increased number of kwh charged to

the theater. A lack of uniformity exists in the rates in various localities even where one power company operates in adjacent areas.

The data received indicate that power rates range from a minimum of 1.14¢ to 6¢ per kwh, up to 6000 kwh a month; 1.13¢ to 4.06¢ up to 15,000 kwh a month; and from 0.99¢ to 2.49¢ up to 30,000 kwh a month. The committee has compiled a chart covering 57 widely separated cities of populations greater than 50,000, showing the power available in terms of voltage, phase, and frequency, and the minimum and maximum costs per kwh, in the three power-consumption brackets, namely, 6000, 15,000, and 30,000 kwh per month. This chart clearly shows the lack of uniformity in rate structure and accounts for some of the complaints of theater owners on excessive power bills.

Thirty widely separated cities were selected to determine minimum and maximum costs of operating lighting and power equipment. This analysis shows that charges to a theater having a load of 6 kw, using 750 kwh per month for lighting only, ranged from a minimum of $22 for Los Angeles, Calif., to a maximum of $56 for Miami, Fla. A load of 12 kw (lighting), with a consumption of 1500 kwh, led to charges from $41 to $105 for the same cities. The analysis disclosed also the fact that for a 12-kw load, at 1500 kwh a month, the cost is $22 for Seattle, Wash., and $67 for Boston, Mass. A 30-kw load, at 6000 kwh a month, costs $68 in Seattle and $219 in Chicago. A 75-kw load, at 15,000 kwh a month, costs $178 in Los Angeles and $360 in Denver. A 75-kw load, at 30,000 kwh a month, costs $295 in Los Angeles and $537 in Jacksonville, Fla.

The questionnaire charts distributed widely throughout the industry will show the number and proportion in use of arcs, according to types and power sources, the average seating capacities of theaters, picture sizes, and many other factors. Charts are being prepared showing the proportion of power used and the corresponding costs, for the various theater functions, including projection, lighting, refrigeration, *etc.*, and graphs are being prepared showing the average total costs of power in different localities. It is believed that these graphs will enable exhibitors to determine whether or not they are operating with average electrical efficiency and economy. The survey indicates that an amount of the order of 20 million dollars a year is expended for electric power to operate theater equipment, for a power consumption ranging from 600 to 800 million kwh yearly, and for a connected capacity exceeding 600,000 kw.

TABLE I

Power Available in Various Cities

				30 Kw 6000 Kwh		75 Kw 15,000 Kwh		75 Kw 30,000 Kwh	
	Voltage	Phase	Cycles	Min.	Max.	Min.	Max.	Min.	Max.
Albany, N. Y.	120–208	1–3	60	2.35		1.69	2.11	1.09	1.46
Atlanta, Ga.	120–208	1–3	60	2.01	3.44	1.79	2.05	1.45	1.57
Atlantic City, N. J.	120–208	1–3	60	3.03	3.06	2.46		1.70	
Baltimore, Md.	120–208	1–3	60	2.85		2.45		1.79	
Boston, Mass.	120–208	1–3	60	2.95	2.98	2.40	2.59	1.56	1.64
Brockton, Mass.	120–208	1–3	60	2.64		1.95	2.21	1.36	1.49
Buffalo, N. Y.	120–208	1–3	25 & 60	1.51		1.05	1.69	.80	1.05
Canton, Ohio	117 1/4–204	1–3	60	2.97	3.00	2.22		1.50	
Chicago, Ill.	120–208	1–3	60	3.34		2.05	2.53	1.52	1.76
Cincinnati, Ohio	120–208	1–3	60	2.77	2.96	2.25	2.42	1.52	1.74
Columbus, Ohio	120–208	1–3	60	2.02	2.22	1.81	2.12	1.31	2.06
Dallas, Texas	115–230	1–3	60	2.69		2.21		1.57	
Dayton, Ohio	114–199	1–3	60	2.58		2.27		1.40	1.75
Denver, Col.	120–208	1–3	60	2.60		2.40		1.63	
Detroit, Mich.	120–208	1–3	60	2.85	2.99	2.58		1.66	
	120–240	1–3	60						
Evanston, Ill.	115–200	1–3	60	3.01	4.24	2.47	2.72	1.71	1.83
Fort Wayne, Ind.	120–208	1–3	60	1.75		1.59	2.14	1.40	1.55
Fort Worth, Tex.	120–208	1–3	60	3.00		2.41		1.70	
Harrisburg, Pa.	120–208	1–3	60	2.79	3.53	2.21	0.47	1.47	1.49
Houston, Texas	122–211	1–3	60	2.13		2.17	2.19	1.44	1.46
Indianapolis, Ind.	120–208	1–3	60	1.83	3.06	1.90		1.33	
Knoxville, Tenn.	115–199	1–3	60	1.30		1.30		.95	
Lincoln, Neb.	120–208	1–3	60	1.46	2.24	2.04	1.97		
Long Beach, Calif.	120–208	1–3	50–60	2.03	2.82	1.51	2.65	1.22	1.70
Louisville, Ky.	120–208	1.3	60	2.51	2.53	1.97		1.36	
Lynn, Mass.	120–208	1–3	60	2.63		1.76		1.64	
Madison, Wis.	120–208	1–3	60	1.65	2.24	1.56	2.16	1.16	1.62
Memphis, Tenn.	120–208	1–3	60	1.73		1.13		1.57	
Miami, Florida	115–230	1–3	60	2.27	4.03	2.75		2.05	
Milwaukee, Wis.	120–208	1–3	60	2.10	3.22	1.79	2.54	1.44	1.90
Minneapolis, Minn.	120–208	1–3	60	2.55	2.88	1.91	2.47	1.46	1.84
Mount Vernon, N. Y.	120–208	1–3	60	3.87	4.81	2.94	4.06	2.11	2.55
New Orleans, La.	120–208	1–3	60	2.68		2.06	2.40	1.48	1.65
New York, Bronx	122–211	1–3	60	5.16		2.52	3.46	1.97	2.39
Brooklyn	122–211	1–3	60	4.86		2.57	3.46	1.67	2.39
Manhattan	122–211	1–3	60	5.16		3.17	3.46	2.09	2.39
Queens	122–211	1–3	60	3.44	5.16	2.13	3.46	1.64	2.39
				2.97	6.00	1.99		1.48	
Richmond	110–220	1–3	60	3.17	3.39	2.24		1.70	
Newark, N. J.	120–208	1–3	60	3.12		2.47	3.05	1.57	2.00
Oak Park, Ill.	115–199	1–3	60	3.61	4.24	2.47	2.72	1.71	1.83
Oklahoma City, Okla.	120–208	1–3	60	2.17	4.00	1.98		1.21	1.51
Philadelphia, Pa.	115–230	1–2	60	2.84		1.90	2.01	1.25	1.30
Pittsburgh, Pa.	115–199	1–3	60	2.37		1.96		1.23	
Portland, Oregon	123–213	1–3	60	1.14	2.37	1.53	1.87	1.16	1.38
Providence, R. I.	120–208	1–3	60	1.74	2.17	1.77	1.80	1.22	1.30
Richmond, Virginia	120–208	1–3	60	2.37		1.65	2.22	1.33	1.73
Rochester, N. Y.	120–208	1–3	25 & 60	2.74	2.99	1.97	2.64	1.27	1.61
St. Paul, Minn.	120–208	1–3	60	2.68	2.88	2.07	2.77	1.59	1.86
San Antonio, Tex.	120–208	1–3	60	2.06	2.14	1.63	1.86	1.09	1.22
San Francisco, Cal.	122–211	1–2–3	60	1.47	1.93	1.54		1.19	
Scranton, Pa.	120–208	1–3	60	2.44	2.97	1.75	2.33	1.27	1.61
Seattle, Wash.	120–208	1–3	60	1.14	2.05	1.42	1.77	.99	1.11
		1–3	60						

TABLE 1 (*Continued*)

	Voltage	Phase	Cycles	30 Kw 6000 Kwh Min.	30 Kw 6000 Kwh Max.	75 Kw 15,000 Kwh Min.	75 Kw 15,000 Kwh Max.	75 Kw 30,000 Kwh Min.	75 Kw 30,000 Kwh Max.
South Bend, Ind.	120–208	1–3	60	2.68	2.97	2.21		1.57	
Spokane, Wash.	120–208	1–3	60	1.33	1.87	1.77		1.23	
Springfield, Mass.	120–208	1–3	60	2.00	2.91	2.51	3.83	2.67	1.67
Toledo, Ohio	120–208	1–3	25 & 60	3.120	4.34	2.30	2.79	1.55	1.84
Washington, D. C.	120–208	1–3	60	2.00	2.29	1.61	2.16	1.32	1.62
Wichita, Kansas	115–199	1–3	60	2.54		2.24	2.69	1.41	1.59
Wilmington, Del.	120–208	1–3	60	2.49	3.09	2.13	2.47	1.50	2.31
Worcester, Mass.	120–208	1–3	60	2.58	3.10	1.85	3.36	1.36	2.49
Yonkers, N. Y.	120–208	1–3	60	3.67	4.27	2.52	3.49	1.83	2.23

Tools, Tolerances, and Safety Factors

For many years it has been the viewpoint of the Projection Practice Sub-Committee that a study should be made of projector mechanisms in use in theaters to determine the best operating adjustments for various tension devices, the limits of permissible or tolerable wear of mechanical parts, and methods of determining these factors. The corresponding measurements require that consideration be given to the development of inexpensive tools as an aid in making such determinations in the theater. After a careful study of the projector and sound-head mechanisms, the Working Committee on Tools and Tolerances picked as its first objective the determination of the most suitable gate tension consistent with tolerable picture jump.

In order to coördinate the work with any data available from other sources, various projector manufacturers were consulted as to what standards of gate tension were employed during manufacture of the equipment. The replies disclosed the fact that only one manufacturer set a definite numerical standard for picture-gate tension, the others depending upon experienced mechanics to make adjustments through observation of actual operation of the machine.

For experimental studies, two types of spring tension gauges were used. Results obtained by the form that pulls a piece of film through the gate were not sufficiently consistent. The other form, which measured the pressure of the tension shoe, gave more nearly uniform readings; however, it can be used only with the gate removed from the projectors.

During the past few months, tests have been made on projectors in theaters throughout the New York area and it was found that the tension shoe pressure varied considerably from theater to theater, and between projectors in the same theater. At the present time attempts are being made to determine the minimum pressure that can be used while yet keeping the picture jump within allowable limits.

At the same time a study will be made to determine how picture-gate tension affects wearing of the intermittent sprocket teeth and the sprocket-holes in the film.

Fire Hazards

Last year the report on fire hazards comprised an extensive proposed revision of the "Regulations" of the National Board of Fire Underwriters for nitrocellulose motion picture film, as recommended by the National Fire Protection Association.

The Committee is pleased to report that these recommendations were adopted by the NBFU and the NFPA almost in their entirety and were published on July 1, 1939, as NBFU Pamphlet No. 40.

Last spring an invitation was received by the Committee from the National Fire Protection Association to delegate a person to address the meeting of the fire marshals on the opening day of the NFPA Convention, May 7, 1940, at Atlantic City, N. J. Mr. Sylvan Harris was appointed to attend the Convention and to make the address. The valued coöperation of the State of Connecticut was received, through the official appointment of Inspector E. A. Morin to attend the Convention and present a special exhibit of a model projection room and other displays to the delegates. The address included a general review of the efforts of the motion picture industry to improve the design and operation of motion picture projection rooms, and particularly from the standpoint of fire prevention and fire control. Attention was called to the chaos that existed in such matters a number of years ago when the Society first began to issue its recommended projection room plans. The recent general improvement in conditions was described, but attention was called to the fact that even at this late date numerous inconsistencies and conflicts exist throughout the country in the fire regulations and building codes of the various states and municipalities. The building codes for motion picture theaters require much revision and standardization, and a plea was made that steps be taken to correct the situation. An invitation was extended to the fire marshals, the NFPA, the NBFU, and various other organizations to coöperate with the SMPE in presenting to the fire prevention authorities all over the country the need for greater uniformity and logical consistency in the establishment of fire regulations.

Subsequently to the NFPA Convention, and as a result of the exhibition of the model projection room, requests for further information

concerning the work of the State of Connecticut were received from the Department of Public Safety of the City of Rochester, N. Y., and from the Provincial Fire Commissioner's Office of the Province of Quebec, Canada.

Some items not covered in the previously mentioned revision of the NFPA "Regulations" are still under consideration, and the Working Committee on Fire Hazards intends to have material on these matters ready for a report at the next Convention.

There are also under consideration the possible ways of acquiring reliable and complete information as to the causes of film fires in projection rooms and also means for analyzing the data as obtained.

Screen Brightness and Illumination Meters

During the past year this Working Committee has given consideration to the subject of meters for measuring light reflected from the screens of motion picture theaters. It is hoped to report definitely at the Spring Meeting of the Society on the type or types of meters found to be most suitable for this purpose.

The subject of photometric nomenclature and conversions is of great interest to the Sub-Committee on Projection Practice, as well as to other committees of the Society. The following analysis of the subject by Mr. Sylvan Harris, originally intended for publication as an individual paper, has been included in this report as useful and informative material.

PHOTOMETRIC NOMENCLATURE AND CONVERSIONS

Photometric nomenclature and conversions between various units are involved in the work of the Projection Practice Sub-Committee, as well as the Standards Committee, and to a considerable extent at present. Particularly is this the case with respect to the establishment of suitable standards of illumination for motion picture screens. The multiplicity of photometric terms and units has often led to difficulty and, in some cases, even to serious confusion, especially in attempting to interpret literature on photometric subjects and in reconciling measurements of various groups of investigators. As far as is known, no publication is available in which any attempt has been made to organize the entire system of photometric nomenclature into a logical and systematic whole. The purpose of the present work is to fill this need.

Nomenclature

First, there are presented the fundamental relations upon which the photometric nomenclature depends:

Luminous Source.—The starting point of photometric measurements is the "candle." A standard or unit candle is said to have an *intensity* of one "candle-power."

Luminous Flux.—The *quantity of visible radiation* emitted by a source is stated in terms of the *lumen.* The lumen, as will be shown below, is $^1/_{4\pi}$ of the total flux emitted by a point-source radiating luminous energy uniformly in all directions.

Illumination, or Flux-Density.—The terms "illumination" and "flux-density" are synonymous. Let a point-source of light emit luminous energy uniformly in all directions. Then the flux-density on the surface of a sphere of radius r circumscribed about the point-source is

$$E = \frac{\varphi}{4\pi r^2} \qquad (1)$$

where E is the flux-density and φ is the total flux. The dimensions of E are thus units of flux per unit of area. The various units are given in Table I. It is to be carefully noted that when several terms occur in the same block of the table, these terms are synonymous and equivalent.

TABLE I

Illumination

Where φ is in	and r is in	E is in
lumens	cm	lumens/sq-cm cm-candles phots
lumens	m	lumens/sq-m meter-candles lux
lumens	inch	lumens/sq-in inch-candles
lumens	ft	lumens/sq-ft ft-candles

Intensity of the Source.—For the purpose of comparing the intensities of sources, it is convenient to refer the flux-density to a sphere of unit radius. Thus, in equation *1* let $r = 1$ and substitute I for E, which gives

$$I = \frac{\varphi}{4\pi} \tag{2}$$

Intensity is thus the flux-density (or illumination) referred to unit distance from the source. The area of a unit sphere is the same as the number of steradians of solid-angle (ω) about the point-source, so the dimensions of I are units of flux/steradian. This unit is also called "candle-power," or simply the "candle."

TABLE II

Intensity

Where φ is in	and ω is in	I is in
lumens	sterad	lumens/sterad candles

Brightness, or Intrinsic Brilliancy.—Brightness is defined as the luminous intensity of the source per unit of projected area of the source; or, letting b = brightness and A = area of the source:

$$b = \frac{I}{A} \tag{3}$$

The source whose brightness is being calculated may be either a primary source (or an original radiator) or a secondary source (a reflector). The dimensions of brightness b are thus units of flux per steradian per unit of area, or candles per unit of area. The various units are given in Table III.

TABLE III

Brightness (In Terms of Intensity)

Where I is in	and A is in	b is in
candles lumens/sterad	sq-cm	candles/sq-cm lumens/sterad/sq-cm stilb
candles lumens/sterad	sq-m	candles/sq-m lumens/sterad/sq-m
candles lumens/sterad	sq-in	candles/sq-in lumens/sterad/sq-in
candles lumens/sterad	sq-ft	candles/sq-ft lumens/sterad/sq-ft

In equation *3* and Table III, brightness has been defined in terms of intensity. It may be expressed also in terms of flux. The brightness of a luminous surface emitting one lumen per sq-cm is known as the *lambert.* The dimensions of this unit are units of flux per unit

TABLE IV

Brightness (In Terms of Flux)

Where φ is in	and A is in	b is in
lumens	sq-cm	lumens/sq-cm lamberts
lumens	sq-m	lumens/sq-m meter-lamberts apostilb
lumens	sq-in	lumens/sq-in inch-lamberts
lumens	sq-ft	lumens/sq-ft ft-lamberts

of area, the same as the dimensions of illumination units, and an analogous set of terms has come into use. Thus, if the illumination of a surface is 1 ft-candle (= 1 lumen/sq-ft) and the reflectance of the surface is 100 per cent, the reflected flux-density will be 1 lumen/-sq-ft and the brightness 1 ft-lambert. The various terms are given in Table IV.

Conversions

Since the terms in Table I, III, and IV are specified in various units of area (sq-cm, sq-m, sq-in, sq-ft), conversions may be made from one term to another *within a given table.* The "internal" conversions of Tables I, III, and IV are given in Tables V, VI, and VII. The conversion factors are given both in operational and numerical forms.

In using the tables, the factors shown are employed when passing to the right and upward. When passing from the top downward and then to the left, the reciprocals are used, thus:

$$\text{ft-candles} = 10.764 \times \text{meter-candles}$$

$$\text{meter-candles} = \frac{1}{10.764} \times \text{ft-candles}$$

In addition to the "internal" conversions, an "external" conversion is possible between Tables III and IV, since brightness is expressed in two ways—in terms of intensity and in terms of flux.

TABLE V

Illumination

	lumens/sq-cm cm-candles phots	lumens/sq-m meter-candles luces*	lumens/sq-in inch-candles	lumens/sq-ft ft-candles
lumens/sq-cm cm-candles phots	1	$(100)^2$ = 10,000	$(2.54)^2$ = 6.4516	$(2.54 \times 12)^2$ = 929.030
lumens/sq-m meter-candles luces*	$\left(\frac{1}{100}\right)^2$ = 0.0001	1	$\left(\frac{2.54}{100}\right)^2$ = 0.000645	$\left(\frac{2.54 \times 12}{100}\right)^2$ = 0.092903
lumens/sq-in inch-candles	$\left(\frac{1}{2.54}\right)^2$ = 0.15500	$\left(\frac{100}{2.54}\right)^2$ = 1550.00	1	$(12)^2$ = 144
lumens/sq-ft ft-candles	$\left(\frac{1}{2.54 \times 12}\right)^2$ = 0.0010764	$\left(\frac{100}{2.54 \times 12}\right)^2$ = 10.764	$\left(\frac{1}{12}\right)^2$ = 0.006944	1

* Plural of "lux."

TABLE VI

Brightness (In Terms of Intensity)

	candles/sq-cm lumens/sterad/ sq-cm stilb	candles/sq-m lumens/sterad/ sq-m	candles/sq-in lumens/sterad/ sq-in	candles/sq-ft lumens/sterad/ sq-ft
candles/sq-cm lumens/sterad/sq-cm stilb	1	$(100)^2$ = 10,000	$(2.54)^2$ = 6.4516	$(2.54 \times 12)^2$ = 929.030
candles/sq-m lumens/sterad/sq-m	$\left(\frac{1}{100}\right)^2$ = 0.0001	1	$\left(\frac{2.54}{100}\right)^2$ = 0.000645	$\left(\frac{2.54 \times 12}{100}\right)^2$ = 0.092903
candles/sq-in lumens/sterad/sq-in	$\left(\frac{1}{2.54}\right)^2$ = 0.15500	$\left(\frac{100}{2.54}\right)^2$ = 1550.00	1	$(12)^2$ = 144
candles/sq-ft lumens/sterad/sq-ft	$\left(\frac{1}{2.54 \times 12}\right)^2$ = 0.0010764	$\left(\frac{100}{2.54 \times 12}\right)^2$ = 10.764	$\left(\frac{1}{12}\right)^2$ = 0.006944	1

TABLE VII

Brightness (In Terms of Flux)

	lumens/sq-cm lamberts	lumens/sq-m meter-lamberts apostilbs	lumens/sq-in inch-lamberts	lumens/sq-ft ft-lamberts
lumens/sq-cm lamberts	1	$(100)^2$ = 10,000	$(2.54)^2$ = 6.4516	$(2.54 \times 12)^2$ = 929.030
lumens/sq-m meter-lamberts apostilbs	$\left(\frac{1}{100}\right)^2$ = 0.0001	1	$\left(\frac{2.54}{100}\right)^2$ = 0.000645	$\left(\frac{2.54 \times 12}{100}\right)^2$ = 0.092903
lumens/sq-in inch-lamberts	$\left(\frac{1}{2.54}\right)^2$ = 0.15500	$\left(\frac{100}{2.54}\right)^2$ = 1550.00	1	$(12)^2$ = 14.4
lumens/sq-ft ft-lamberts	$\left(\frac{1}{2.54 \times 12}\right)^2$ = 0.0010764	$\left(\frac{100}{2.54 \times 12}\right)^2$ = 10.764	$\left(\frac{1}{12}\right)^2$ = 0.006944	1

The flux emitted by a flat element of diffusing surface is shown in textbooks on photometry to be $\varphi = \pi I$. Substituting in equation *3*, the brightness, in intensity units, is*

$$b = \frac{1}{\pi}\left(\frac{\varphi}{A}\right) \tag{4}$$

If $\varphi/A = 1$ flux unit of brightness (*e. g.*, 1 lambert), $b = 1/\pi$ intensity unit (*e. g.*, 1 candle/sq-cm), or

$$\text{intensity units} = \pi \times \text{flux units} \tag{5}$$

Conversion between Tables III and IV therefore involves π. The various "external" conversion factors are given in Table VIII.

TABLE VIII

Brightness

	lumens/sq-cm lamberts	lumens/sq-m meter-lamberts apostilbs	lumens/sq-in inch-lamberts	lumens/sq-ft ft-lamberts
candles/sq-cm lumens/sterad/sq-cm stilbs	π = 3.1416	$\pi(100)^2$ = 31416	$\pi(2.54)^2$ = 20.268	$\pi(2.54 \times 12)^2$ = 2918.6
candles/sq-m lumens/sterad/sq-m	$\pi\left(\frac{1}{100}\right)^2$ = 0.00031416	π = 3.1416	$\pi\left(\frac{2.54}{100}\right)^2$ = 0.0020268	$\pi\left(\frac{2.54 \times 12}{100}\right)^2$ = 0.29186
candles/sq-in lumens/sterad/sq-in	$\pi\left(\frac{1}{2.54}\right)^2$ = 0.48695	$\pi\left(\frac{100}{2.54}\right)^2$ = 4869.5	π = 3.1416	$\pi(12)^2$ = 452.39
candles/sq-ft lumens/sterad/sq-ft	$\pi\left(\frac{1}{2.54 \times 12}\right)^2$ = 0.003381	$\pi\left(\frac{100}{2.54 \times 12}\right)^2$ = 33.81	$\pi\left(\frac{1}{12}\right)^2$ = 0.021817	π = 3.1416

Reflection Factor.—Reflection factor is the ratio of the light-flux emitted by a secondary source (*i. e.*, a reflector) to the light-flux incident upon the secondary source from the primary source.

* This formula is based upon the assumption that the reflecting surface is completely diffusing; *i. e.*, the reflection follows Lambert's law.

Let φ_i be the incident flux and φ_r the reflected flux. The reflection factor is then

$$f = \frac{\varphi_r}{\varphi_i}$$

Since $\varphi_r = \pi b A$ (eq. *4*) and $\varphi_i = EA$ (equation *1*),

$$f = \frac{\pi b}{E}$$

The intensity units of brightness are the basic units, and must be used in all formulas involving b. If the brightness is given in flux units they must be converted to intensity units, thus:

$$f = \frac{\pi \times \text{intensity units}}{\text{illumination}} \qquad e.\,g.,\ f = \frac{\pi \times \text{candles/sq-ft}}{\text{ft-candles}}$$

$$= \frac{\pi \times \left(\frac{1}{\pi} \times \text{flux units}\right)}{\text{illumination}} \qquad = \frac{\pi \times \left(\frac{1}{\pi} \times \text{ft-lamberts}\right)}{\text{ft-candles}}$$

$$= \frac{\text{flux units}}{\text{illumination}} \qquad = \frac{\text{ft-lamberts}}{\text{ft-candles}}$$

REPORT OF SUB-COMMITTEE ON THEATER DESIGN

Among the activities of the Sub-Committee on Theater Design is a project that is sufficiently advanced for presentation at the Spring Convention, 1941. This project involves preparing a glossary or system of nomenclature of terms for use in connection with the subject of theater design. Lack of consistent and clear nomenclature has handicapped the work of this Sub-Committee, and also has led to the confusion existing in the field because of certain inappropriate terms as well as multiplicity of terms sometimes used in reference to the various items of consideration in theater design.

All phases of theater design are covered in the compilation of this glossary. Included are the acoustic, seating, viewing, traffic, projection, auditorium and auditorium lighting, and ventilating phases. Approximately 250 terms have been compiled with the aid of engineers and architects in the various fields of endeavor connected with this work. The Sub-Committee is now occupied in formulating

the proper definition for these terms. In many instances certain terms and definition will be taken from sources already established as standard.

This Sub-Committee has also made a study of the use of staggered seating in motion picture theaters. Staggered seating exists in all theaters in which the seating width of the auditorium is greater than fourteen seats. This is so because of the magnitude of the angle subtended to the screen from positions on either side of the centrally located fourteen seats, and also because the seats are initially placed directly behind one another in lines parallel to the center-line of the auditorium. In these cases, however, the stagger effect does not exist in the central bank of chairs when the chairs are placed directly behind one another in lines parallel to the center-line of the auditorium.

It was noted that the view of the screen was unobstructed from the side seats, which had the stagger effect, whereas serious obstruction of the view of the screen was evident in the same theater on the same floor slope from the centrally located seats. It has been found generally that the usual floor slope in the motion picture theater auditorium was sufficient for the side seating sections having the stagger effect, but not sufficient for the central seating section. It has also been found that if the floor slope were to be increased to make it possible to have unobstructed vision of the screen from the central section of seats, the slope would be excessive and dangerous from the hazard standpoint and would create serious difficulties in the functional design of the theater. In many cases the screen has been placed at an undesirable height above the floor to overcome obstruction difficulties.

It is therefore proposed that where floor slopes become too great for unobstructed viewing of the screen or where the screen would otherwise be placed too high, the central section of seats be placed so that a stagger effect is produced. This means that every alternate row of seats in the central section would have only one seat less than the row behind, or before, and would result in a total loss of seats amounting to only about $1^1/_2$ per cent of the total.

It is also proposed that in existing motion picture theaters having inadequate floor slopes, the central section of seats be reset according to a stagger system. It is not necessary to stagger the seats in a certain number of the rows nearest the screen because the amount of stagger does not leave sufficient space between the heads of the pre-

ceding spectators to permit a view of the entire picture from those rows. Since only a nominal floor slope is necessary under those seats to achieve unobstructed vision, the seats in this area can be arranged on a non-stagger plan.

Attention is directed to the desirability of a requirement relative to staggered seating laid down by the State of Connecticut. This regulation permits staggered seating provided that the aisle line remains unbroken. This unbroken line is made possible by the use of end-of-row chairs of different width so arranged as to maintain the stagger effect.

Immediate consideration has also been given to the recommendation for the use of green lights behind the exit signs in the auditorium instead of the usual red lights. The green light is favored because it is now a popular conception that a green light denotes safety and in traffic regulation or control means a signal to go ahead. A green light of the proper tone is also more restful and less disturbing to the eyes while viewing the picture. The American Standards Association describes the spectrum of an acceptable green glass as containing yellow, green, blue, and violet, with only a trace of red and orange. This hue is known as "admiralty green" and has a bluish tint when observed by daylight. The ASA may make some slight revision regarding this color in the near future, however, and the use of this particular hue, therefore, should be tested prior to its adoption under the lighting conditions found in the average motion picture auditorium.

A series of surveys of physical and operating conditions in motion picture theaters has been started and is being continued with the aim of obtaining data upon which motion picture theater design may be based.

REPORT OF THE STANDARDS COMMITTEE*

Summary.—*A report of activities of the Committee during the past season, containing a brief discussion of the relation between SMPE Recommended Practices and American Standards and Recommended Practices. SMPE "Standards" no longer exist, according to action of the Board of Governors, but rather SMPE "Recommended Practices." The latter can not become "standards" unless and until approved by the American Standards Association.*

The Standards Committee has been fortunate in having the active coöperation of the Standards Committee of the Research Council of the Academy of Motion Picture Arts and Sciences in the discussion and recommendation of standards and recommended practices of the motion picture industry. An example of this coöperation is the review over the past two years of present standards and recommended practices, and the agreement by the two committees on thirty-three proposals recommended to the Sectional Committee on Motion Pictures (ASA) for adoption as American Standards and Recommended Practices.

In the past there has been some confusion as to standards and recommended practices in the motion picture industry, where we have had the rather ambiguous situation of American Standards and American Recommended Practices approved by the American Standards Association, of SMPE Standards and SMPE Recommended Practices approved by the SMPE, and, I believe, of Research Council Standards and Recommended Practices approved by the Research Council. In many cases these standards were all common to the three organizations. In other cases, however, SMPE Standards were not American Standards or Academy Standards, and *vice versa*. Therefore, in the interest of avoiding confusion and clarifying the situation, so that the Standards Committee could work more effectually, the Board of Governors of the Society at the Atlantic City Meeting, ruled that SMPE Standards, as such, would be abolished and that present SMPE Standards would be known from now on as SMPE Recommended Practices. It is believed that similar action has been taken by the Research Council. Thus the only Standards we now have are those recognized by the American Standards Association, which

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* Presented at the 1940 Fall Meeting at Hollywood, Calif.

formulates these Standards through the Sectional Committee of which the Research Council of the Academy of Motion Picture Arts and Sciences and the SMPE are members. This gives a more workable set-up, and one conducive to far less confusion in the minds of the persons who use these specifications in the motion picture industry. It also calls for close coöperation of the Standards Committees of the SMPE and the Research Council in preparation of Recommended Practices and in suggestions to the Sectional Committee on Motion Pictures.

It is a pleasure to report that the Standards Committees of the Academy and of the SMPE have applied this spirit of close coöperation in many instances in the discussion of proposals of recommended practices in the two organizations. We have at the present time three such projects which have been voted upon favorably at a Standards Committee Meeting, and which, through letter-ballot, have received the final approval of the Standards Committee. These projects have been forwarded to the Editorial Vice-President for publication in the JOURNAL and for final action by the Society. These projects are:

(*1*) Rescinding the current SMPE Recommended Practice for Lantern-Slide dimensions as published in the March, 1938, issue of the JOURNAL on page 255.

(*2*) Approving the following Recommended Practice: "The brightness at the center of the screen for viewing motion pictures shall be 10^{+4}_{-1} foot-lamberts, when the projector is running with no film in the gate." This is a revision of a previous Recommended Practice that the brightness at the center of the screen for viewing motion pictures be between 7 and 14 foot-lamberts when the projector is running with no film in the gate.

(*3*) The adoption as a Recommended Practice of the Academy Research Council Specification for Release-Print Sound Track Dimensions as published in the Research Council Bulletin.

After initial approval of a project at a Standards Committee Meeting final approval requires a two-thirds affirmative vote by letter-ballot of all the members of the Committee. This appears to contain some element of injustice, as it may happen that those disapproving, although less than one-third of the voting membership of the Committee, may be those most vitally concerned with the specific proposal. This thought has been passed on to our Engineering Vice-President for possible revision of this procedure by the Board of Governors.

In addition to the above proposals there is in process at the present time a letter-ballot for voting on the adoption as an SMPE Recommended Practice, and for submittal to the Sectional Committee on Motion Pictures, a revision of the present SMPE Recommended

Practice on film perforation specification, which, we believe, will be more in line with actual practice and will be much more widely accepted than our present Recommended Practice. This also has been the result of the coöperation between the Society and the Research Council.

Many other active subjects are being considered by the Standards Committee. These include: A General Glossary of Technical Terms; Sound-Track Nomenclature; Release Print Leader Specifications; Raw-Stock Cores; Designations of Types of Winding of Rolls of 16-Mm Sound-Film Raw Stock; Edge-Numbering of 16-Mm Film; Sprockets; Sound-Transmission Characteristics of Screens; Projector and Camera Apertures; and Standard Volume Indicator.

We wish to appeal to the other technical committees of the Society, to individuals, and to industrial and producing companies to feel free to suggest subjects they believe should become SMPE Recommended Practices or American Standards. The Standards Committee as such is a deliberative committee. When subjects are suggested for standardization requiring considerable investigation and development, they are referred to the appropriate Committee of the Society.

We have had four meetings during this current year, with an average attendance of fourteen members at each meeting, and have had correspondence from other members who because of the distance involved or other unavoidable matters could not attend. Our discussions at the meetings have been facilitated by the preliminary work of sub-committees made up of members of the Committee who are particularly interested or expert in that specific branch of the motion picture field. The Chairman wishes to take this opportunity to thank the members of the Committee and others who have assisted with their suggestions in a helpful and friendly spirit leading to frank discussions of the subjects under consideration.

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REPORT OF THE TELEVISION COMMITTEE*

Summary.—*The Television Committee of the Society during the past year has carried out a considerable amount of work as listed:*

(*1*) *Flicker and visual fatigue in television has been studied, a preliminary report on which work is presented herein.*

(*2*) *A study of the most suitable type of film for television transmissions has been carried out, a report on which will be presented also.*

(*3*) *More material has been added to a bibliography and glossary of terms in the field of television, which work was started more than a year ago and which still continues.*

PRELIMINARY REPORT OF THE SUB-COMMITTEE ON FLICKER AND VISUAL FATIGUE

General.—Since early May of this year, a sub-committee has been actively studying the problem of frame** frequency in television. In this assignment, it was instructed to correlate available information on the subject as affected by three major factors, namely:

(*1*) Flicker.
(*2*) Portrayal of motion.
(*3*) Visual fatigue.

The need for such a fact-finding committee has become more apparent within the past year and it was felt at the outset that the motion picture industry as a whole was peculiarly well situated to assist television in this work. Because of its familiarity with existing experience, the ability within its ranks, and its tools for prosecuting new experimental work when the need for such work was determined, the Society of Motion Picture Engineers is in a particularly favorable position to sponsor such work.

The first task was to index and abstract as much of the existing literature as seemed pertinent and possible. Following this work, the gaps in existing knowledge would be more apparent and as the need for further work was apparent, experiments and means for performing them could be devised.

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* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 9, 1940.

** Frame. This term denotes the number of times the entire picture has been scanned per second.

This report covers the first part of this program.

Bibliography.—A list of the articles and books found to date relating to this subject is appended. It is not hoped that this is complete and since it is only necessary that the information obtained be comprehensive, pertinent, accurate, and descriptive of the essential facts, completeness in the bibliography was not considered vital.

Summary of Findings.—Since television observation, as a visual task, is not essentially different from motion picture observation, it is possible to correlate data from the latter field for direct use in the

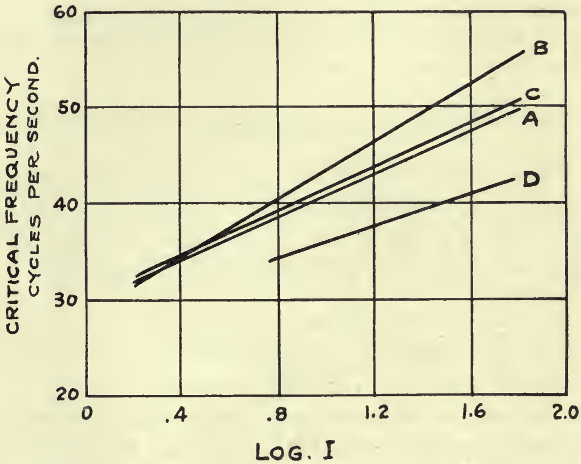

FIG. 1. Critical frequency *vs.* log intensity for 4 degrees diameter of stimulation area for 4 subjects (*P. A. Snell, J. Soc. Mot. Pict. Eng., May, 1933, p. 367*).

former. One important element in such considerations is the average brightness level found in current practice.

General experience shows that visual fatigue accompanies any prolonged visual task and since motion picture observation can be no exception to this, it is not to be expected that television observation will be an exception. Opthalmological research has revealed the importance of object brightness in the problem of visual fatigue; therefore, data on the present screen-brightness practice in the motion picture theater is of fundamental importance to the object of this work. The data submitted have a direct bearing on the television problem since some general knowledge obtained from practical or

every-day experience is available to everyone and correlated technical data are available to the specialist from the field of motion pictures.

A survey made early in 1940 and covering a group representative of the larger theaters in the United States (seating capacity from 2300 to 3500) shows a range of central screen brightness of from 6 to 10 foot-lamberts, as reported by Mr. A. C. Downes of the National Carbon Company. These measurements were made with the projector operating without film. For the smaller theaters, which are in the

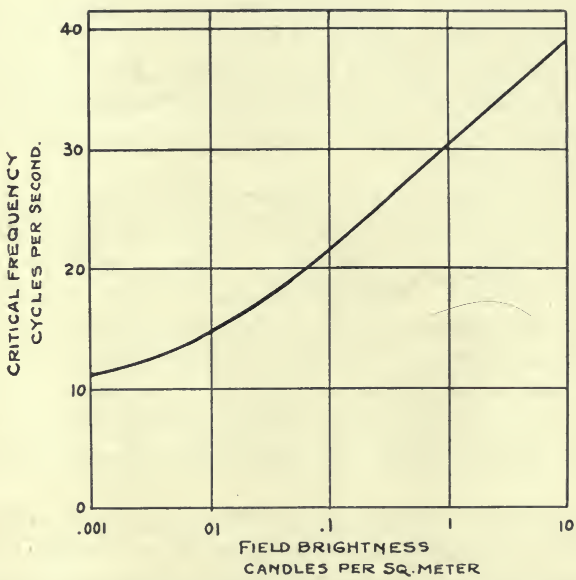

FIG. 2. Critical frequency *vs.* brightness for square wave—white light illumination cycle (*Fig. 94, "Principles of Optics," Hardy and Perrin, McGraw-Hill Book Co., New York*).

vast majority, it has been reported that a comparative figure would be about $4^1/_2$ foot-lamberts under similar and favorable conditions.

Since these figures are significant in the study of flicker and visual fatigue, they are included in this report in order that the present practice may be correlated with the optical requirements. Reports from foreign sources indicate that brightness levels of the order of 10 foot-lamberts are being realized. This falls within the range of 10^{+4}_{-1} foot-lamberts which is the present SMPE Recommended Practice.

Flicker.—Since the visual apparatus does not respond instantly to a stimulus or to its removal, persistence of vision can prevent flicker from being observed. It has been shown that above the frequency at which flicker is not observable, the apparent brightness of an object viewed in interrupted illumination is the average brightness, provided the illumination is continued for more than 3 per cent of the cycle. It should be noted that under the most favorable conditions of brightness and flicker frequency, the least perceptible change in brightness is of the order of 1.5 per cent.

The sensitivity of the eye to flicker has been tested by numerous investigators who agree in general that the frequency at which the phenomenon disappears, called the critical frequency, is a linear function of the logarithm of the brightness within the range of present interest. Certain authors carefully specify a constant area of stimulation (see Figs. 1 and 2).

At least one authority is convinced that flicker is still apparent on the screen and, furthermore, feels that present brightness levels are so low that a change in the direction of "easiest seeing" would result in still greater flicker. It seems, however, to have been generally granted that the flicker situation has been considerably improved.

The seriousness of flicker is due to the duration of the exposure when observing motion pictures of television programs. It has been found that at a constant average brightness the percentage duration of the light stimulus during the cycle affects the critical frequency (Fig. 3).

The same authority states that the fundamental component of the Fourier series expressing the stimulus for constant average brightness exerts a major control on the critical frequency except when the stimulus is *off* for only small percentages of the cycle, in which case the perception, as well as the further depression of the critical frequency, is due to the higher order components. The critical frequencies were found to be lower when the surroundings were dark than when they were made equal in brightness to the field of the test and that results for a reduction of the field of test to $^1/_5$ with surroundings left equal to the previously employed field were lower than either. Differential sensitivity as measured by the inverse of the Weber-Fechner fraction $\Delta B/B$ was found to be highest when the test field lay in surroundings of about its own brightness, the sensitivity being lower for darkened surroundings and considerably lower as the surrounding level was increased over that of the test field. These findings are said to be paral-

lel to the relation between sensitivity to brightness difference and comparative brightness conditions of the test field and surroundings. Other investigators have reported similar findings and state that the sensitivity of the eye to flicker is increased when adapted to bright light as well as when the region around flickering area is illuminated.

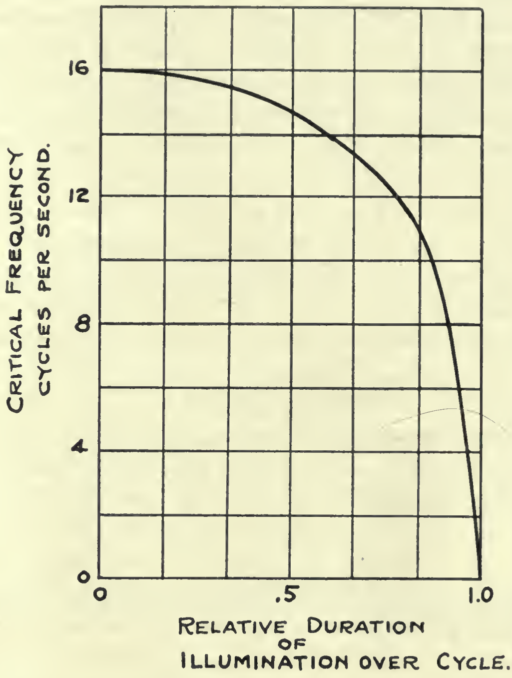

FIG. 3. Variation of critical frequency with relative duration of illumination for spectral blue light in range where critical frequency does not change with intensity (*P. W. Cobb, J. Opt. Soc. Amer., April, 1934, p. 107*).

Maximum sensitivity occurs when the surrounding field is equal to the test field. The process of adaptation continues for as much as a half hour (see Fig. 4).

It is reported that maximum sensitivity to flicker occurs at yellow in the spectrum, being less at either end.

It has been found that the retina is not uniformly sensitive to flicker over its entire surface. The region within 10 degrees of the fovea demands the highest critical frequencies. Since this area is most com-

monly needed for viewing motion picture and television programs it is indicated that results for this area should be satisfied in both fields.

Flicker tests with a cathode-ray tube screen having an exponential decay curve falling to approximately 2 per cent in $^1/_{24}$ second have been reported in which the room lighting was about $^1/_{10}$ foot-candle. At a screen brightness corresponding to 1 foot-lambert, the flicker was said to have been just noticeable at 38 frames per second, noticeable at 35 frames per second, and disagreeable at 28 frames per second. It was concluded from the curves shown and data presented that a satisfactory solution for reduction of the frame frequency under 30 per second would not be found in an exponential light-output decay curve.

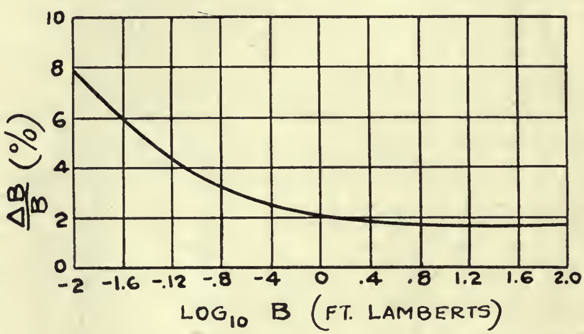

FIG. 4. Weber-Fechner fraction as a function of brightness (*B. O'Brien and C. M. Tuttle, J. Soc. Mot. Pict. Eng., May, 1936, p. 577*).

It is important that effects such as this be reduced to a minimum. Standards of ideal performance should not be dictated by those best equipped visually, but the average of those with "impaired vision" must be seriously considered.

It is apparent that frame frequency is not the only source of flicker either in the theater or on the television screen but since the work of this committee was primarily related to the effects of frame frequency upon certain phases of the television viewing problem, of which flicker was one, no attention has been given to collateral causes and effects of flicker in this field. It is assumed that those effects not being fundamentally subject to Standards having the relationship of the "key and lock," could be considered in other ways.

The Portrayal of Motion.—This problem has been the least satisfactorily treated, the literature being meager to the extent of almost non-existence. Resort has been taken to correspondence with the producers of animated cartoons. Only a few replies have been received at this time. Answers to this correspondence are still expected but so far they do not contain full information of the kind sought.

It is appreciated at the outset that in this regard television is at present under some handicap in relation to the motion picture. In motion picture production sequences having considerable action are taken by careful choice of the most favorable angles. This necessitates use of lenses which will cover a fair depth of field, the remaining inaccuracies being compensated for by the skill of the cameraman. In television, it has not been found possible as yet to use lenses of the same or equivalent depth of field; hence, it seems reasonable to assume that the cameraman will be forced to choose less favorable angles or risk inexact focus. If the former choice is made, the problem of adequate portrayal of motion becomes much more serious especially if the frame frequency is reduced.

It was reported by J. A. Norling of Loucks and Norling Studios, from experience in days of silent pictures when "projected at 16 frames per second, which then was the theoretical projection speed, an animated cartoon thus made showed rather jumpy action but when the frame frequency was increased beyond 16 frames per second. . .this jumpy action became smoothed out."

He continues, "I review these matters merely to add emphasis to the need for a higher picture frequency than the 8 to 12 picture frequency employed in 2-frame exposures and with projection speeds of 16 frames per second to 24 frames per second."

Commenting on the previous problem (flicker), it was further stated that, for light changes such as produced by a shutter, for screen illuminations of as much as 12 foot-candles (produced by no film in the projector), flicker is apparent at 96 periods per second (as obtained from a 3-bladed shutter) but the correspondent indicated that smooth motion and not flicker was the essential problem if reduction of frame frequency were considered.

Mr. D. Fleischer of Fleischer Studios, Inc., stated, "In regard to cartoons, we have found the 24 per second frame frequency the most practical for our use and, as I believe animated cartoons will be an important factor in television, I hope that this will not change in their adaptation to this medium."

Mr. W. E. Garity of the Walt Disney Productions stated that the number of drawings used depended on the speed of the motion being photographed and that "for slow movements, a drawing for every frame is necessary."

The committee is still expecting more complete answers to its correspondence and hopes to amplify this section of its progress report when and if this information becomes available.

Visual Fatigue.—Visual fatigue is a technical phrase employed to indicate that the apparatus of vision has sacrificed some of its reserve capacity for seeing (suffered a decline in activity) as a result of previous activity. It must be carefully distinguished from a physical fatigue. In the latter, consciousness of the fatigue is general, whereas in visual fatigue consciousness of the fatigue is rare and then generally exists due to an over-exercise of the function of vision. At such stages, it can be serious enough to cause injury to sight depending on the nature and cause.

Motion picture and television observation need not be more fatiguing in a visual sense than many other visual tasks, but their seriousness is due to the prolonged activity involved as well as the surrounding conditions. The accompanying visual fatigue is said to be largely retinal and not muscular. The "redeeming" feature of the task when viewing motion pictures, according to one authority, lies in the use of "far vision." In home television, the vision is not so "far" but fortunately, it is not quite as "near" as when reading a book. In this regard, more information is needed to determine the effect of television observation on visual fatigue due to the distance function alone.

The greatest difference in viewing television and motion pictures is in this respect, that most screens in theaters can be assumed to be at a distance of 20 feet or more from the viewer, which for all practical purposes can be considered at infinity, at which point the normal eye is at rest. Whereas, with television, the object can be assumed to be from 6 to 8 feet from the eye, entailing an accommodative action and thus necessitating muscular accomplishments for neither near nor far vision.

Visual fatigue has been found to be occasioned by high degrees of contrast either between adjacent areas in the field of vision (even including the border of the screen) or in time as would be the case due to flicker phenomena, the need to see finer detail, and illumination levels below those associated with "easiest seeing." It is said that the ap-

paratus of vision attempts to compensate for any decreased efficiency and this effort is translated into visual fatigue or even pain and injury to the sight.

One authority states that the present theater levels are far too low for "easiest seeing." If this is correct, television, which generally operates with an average screen brightness below that of large theaters, should devise and make experiments on the visual fatigue involved.

While the level of theater screen brightness is probably actually below that for "easiest seeing," it is probable that the decreased need for discernment of fine detail—the fact that speech and action tell much of the story—reduces the burden, so that even at the present average level of screen brightness the work involved is not in excess in that for other every-day visual tasks of equal duration. Probably the same is true of television to a lesser degree due to other effects. Experimental evidence would be needed for confirmation. It would be complicated by the possible latitude and resolution of the medium.

The resolution of fine detail is limited by visual acuity, which is simply 1/angular size. Greater brightness is required for greater visual acuity. Maximum sensitivity is reached only when the visual angle is not less than about 4 minutes. Continued use of the eyes to discern detail near the limit of visual acuity or near the limit of the Weber-Fechner fraction for brightness difference results in visual fatigue.

Screen surroundings which are less than about $^1/_{100}$ of the field brightness have been proved to be detrimental, causing visual fatigue. In theaters, a border brightness between 0.05 and 0.2 foot-lambert was most frequently chosen when the observer was permitted to choose this level. In the same tests the screen brilliancy chosen was that corresponding to the order of 30 foot-lamberts if the projector had been operated without film. This would correspond under picture conditions with the 10 foot-lambert level generally given for close desk work.

Flicker was mentioned as a prominent cause of visual fatigue. Intermittency of illumination was found not to be a serious cause of visual fatigue provided it was not discernible to the vision as "flicker." Some evidence was found that flicker due to frame frequency is still a factor in visual fatigue in the motion picture theater. However, other causes of flicker may be even more serious.

One has only to look across the beam from the projector in a dark-

ened theater to see that a series of "shocks" are presented to the eye due to the normal shifting of scenes and motion of objects in each scene. Television and the motion picture may, by careful choice, reduce this considerably but it can hardly eliminate it. It seems certain that as the screen brightness increases, more experimental work could very well be done on visual fatigue. The case of seeing and the effect of flicker may have mutually opposite trends under the influence of increased screen brightness but whether or not visual fatigue could be reduced would seem to require experimental verification.

Furthermore, it would seem desirable, if possible, to devise experiments designed to reveal the portion of visual fatigue in any given motion picture or television performance which may be assessed solely to frame frequency.

Future Work.—It is recognized that this report does not consider color. More time will be required to investigate this phase of the problem adequately from the standpoint of flicker and visual fatigue. Likewise, more data are needed on the adequate portrayal of smooth motion as a function of frame frequency. It is believed that some additional work of an experimental nature is desirable to determine effects of certain of these phenomena in the television field. So far as the work has gone, there seems to be a trend of evidence pointing to the conclusion that television will not be on technically safe ground if the frame frequency is reduced below that now in use for motion picture work.

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REPORT OF THE SUB-COMMITTEE ON FILM TESTS

During the latter part of 1939 it became apparent that variations in motion picture print characteristics caused noticeable differences in the quality of television pictures reproduced from motion picture prints. Informal discussions between engineers of the Eastman Kodak Company, Gaumont British Picture Corporation (Baird Television), National Broadcasting Company, and Columbia Broadcasting System led to the formulation of a set of test-films. The set of tests represented a trial-and-error method of establishing an optimum, as it was recognized that the variables involved in television systems precluded the possibility of an exact set of specifications. A set of test-prints was made by the Eastman Kodak Company from a series of negative scenes furnished by the Gaumont British Company. These test-prints were run through the various channels, and observations were made on which prints reproduced best over the television systems.

Only one showing at the studios of NBC (iconoscope), was carried out under the sponsorship of the informal group, and when the SMPE Committee on Television for 1940 was formed, it was decided by the Society Committee that the work of the informal group be continued by them.

Additional showings of the test-prints were carried out at the studios of the Columbia Broadcasting System (image dissector), and the entire set of test-prints was projected by ordinary motion picture projection equipment at the projection theater of Audio Productions, Inc. The prints were then sent to the Farnsworth Television and Radio Corporation, in Fort Wayne, Indiana (image dissector), and subsequently to the RCA Manufacturing Company, of Camden, N. J., for television reproductions on their Orthicon channel.

It was planned that the entire Television Committee group would see the scannings of the test-prints at RCA in Camden but preliminary studies of the film on the Orthicon channel by the engineering group at RCA and by Dr. Peter Goldmark indicated that the results on this channel were so similar to the dissector showings at CBS that nothing would be gained by attendance of the entire Committee at a showing.

Tentative plans were also made for a showing of the prints at the DuMont Laboratories, Passaic, N. J. Because of the pressure of other work at the DuMont Laboratories, it has been impossible to carry out these plans.

Purpose of Film Tests

The original purpose of the film tests was simply to form from visual observation a general idea of whether or not motion picture film prints made to sensitometric standards other than the standards regularly used for normal motion picture projection would produce better final images from television cine film scanning.

A wide range of print characteristics was used, anticipating that the optimum values might be different for different television systems, *i. e.*, iconoscope, image dissector, orthicon. Prints were made both on regular cine positive and on a special fine-grain duplicating positive film to study the effect of positive film-grain sizes. No consideration was given to the sound quality aspects of the problem, which can best be studied by more exact methods.

Characteristics of Test-Films

The test-prints were made from a normal motion picture negative on regular positive film through a positive gamma range of 1.0 to 2.5 and on fine-grain duplicating positive film through a positive gamma range of 1.5 to 2.0. Three prints were made at each gamma value on both types of film, one a normal average density, one lighter (less dense), and one heavier (denser). The visual diffuse density values of these prints are shown in the following table:

Visual Diffuse Density Values—Fine-Grain Emulsion

Gamma		2.5	2.0	1.5
Density range	light	0.17–1.60	0.27–1.57	0.51–1.69
	normal	0.41–2.30	0.59–2.27	0.64–1.92
	heavy	0.86–2.98	1.01–2.80	0.87–2.00

Visual Diffuse Density Values—Standard Emulsion

Gamma		2.5	2.0	1.5	1.0
Density range	light	0.20–1.60	0.22–1.55	0.26–1.30	0.40–1.28
	normal	0.26–1.94	0.42–1.99	0.43–1.50	0.69–1.56
	heavy	0.46–2.40	0.62–2.20	0.62–1.72	0.96–1.80

These gamma values are positive film gammas, not overall effective gammas. The gamma value of the negative from which the prints were made was not known, and, therefore, an exact measure of the overall gamma characteristic of the final print is not available. It may be assumed, however, that the negative was probably developed within the usual negative gamma range, namly, 0.50 to 0.70.

The single print of an additional film made on regular positive was run at some of the showings. The data for this print are not as well known as for the test-prints, but the subject matter involved large areas of extreme white and extreme black. The maximum and minimum densities were 1.98 and 0.28, respectively.

Results of Observations

As might be expected from a set of tests in which so many variables are included, an exact statistical tabulation of opinion is difficult. The Sub-Committee has, therefore, been obliged to interpret in some measure from discussions as well as from written opinion.

All opinions are substantially in agreement in concluding that normal print characteristics are quite acceptable for all the different methods of television film scanning. Print gamma of 1.5 to 2.0 was selected most frequently on iconoscope, dissector, and orthicon, and it is therefore concluded that print gammas should run less than normal rather than over normal if there is to be a variation. Light density prints are preferred and it seems reasonable to assume that this may be tied up in some way to available light factors of television film-scanning equipment.

The comparison of the directly projected prints with the televised results impressed all observers with the ability of all the television channels to reduce the differences between the various test-prints. From this it can probably be said that the television method with its various controls can produce an acceptable result from a wider variation of print characteristics than can be tolerated by normal motion picture projection methods.

It is also apparent from the various viewings that manipulation of the transmitter controls and receiver controls can produce much greater differences in final results than are present in the range of the test-films. This observation tends to verify the conclusion that normal picture film-print characteristics are acceptable at the present time.

The question of fine-grain film *vs.* normal positive film for television print use is not well answered by this set of tests. Some individuals expressed slight preference for the fine-grain results but the opinions were too uncertain to be of real significance. It seems unlikely that differences in grain size of the order involved would materially affect a system with the resolution of the present types of television channels. Some of the observers preferring the fine-grain film expressly stated that their preference was based on differences in tone reproduction rather than graininess as such.

Fine-grain positive films are of major interest, however, from the sound-reproduction standpoint and in view of the fidelity capabilities of the audio portions of present television systems, it may be that fine-grain print stocks will be of value if better overall audio-frequency response characteristics result from the use of such a print medium.

The showing of the additional film referred to before was considered by all observers to be poor over a television channel but satisfactory through a projector. The indication from this is that certain types of subject matter and lighting will not give acceptable results over a television channel, although the prints give a satisfactory projection.

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REPORT OF THE COMMITTEE ON PRESERVATION OF FILM*

Summary.—*A statement of the work of the Committee as a whole and individual reports of sub-committees on the following subjects: (I) Handling and Winding of Film; (II) Safe and Economical Storage, size of vent per unit weight of film determined; (III) Printers for Old and Shrunken Film.*

In keeping with the division of labor agreed to at a meeting of the Committee in New York City on October 13, 1937, and reported in the March, 1938, issue of the JOURNAL, various sub-committees of the Committee as a whole undertook original studies (and experiments when necessary) on assigned subjects as indicated in the above summary. The report of the work on these assignments follows.

(I) THE HANDLING AND WINDING OF FILM

Film for archival purposes should be particularly free from physical defects. Common defects caused by improper handling include scratches on the base or emulsion or both, embedded dirt, finger prints, oil spots, edge malformation, and perforation damage.

Sources of dirt include imperfect processing, flaked film from the edges or the perforation area, rust from rewinding equipment, paint from walls and equipment, dirt from shoes, lint from clothing, dirty packages, shipping cans, and clothing.

To obviate the above sources of dirt, stains, and scratches, the following suggestions are offered:

(*1*) Processing solutions should be free from suspended particles and the drying air carefully filtered. Lubrication of the processed film[1] will tend to minimize scratching and cinching.

(*2*) The air supplied to rooms in which film is handled should be filtered, even if water-washed, because the latter treatment does not remove oily particles. Desirable conditions are a temperature of from 68° to 70°F and a relative humidity of from 55 to 65 per cent, which will insure a minimum propensity of the film to generate static and attract dust particles. On the other hand, if the relative humidity is too high, this is likely to cause ferrotyping or the formation of glossy patches when the film is wound in a roll.

* Presented at the 1940 Fall Meeting at Hollywood, Calif.

(*3*) The corners of rooms should be rounded to permit effective cleaning, the rooms should contain a minimum of dust-accumulating furniture which should be preferably of stainless steel, while the floors and walls should be easily cleaned. Glazed tile walls and waxed linoleum or rubber covered floors are satisfactory. Work benches should be light in color so that dirt can be detected readily, and should be well illuminated.

Workers should wear white starched uniforms of lint-free materials and handle the film with lintless white gloves. Face powders, hair lotions, and finger rings are obvious causes of film defects.

Design of Film-Handling Equipment

Extreme precautions must be taken in the design of film-handling equipment to insure that film is not damaged during handling. Particular attention should be given to the following:

(*1*) *Alignment of Rewinds.*—Any slight misalignment causes the edges of the film to scrape against some part of the mechanism, producing dust apart from damage to the film.

(*2*) *Tight Roll Devices.*—Reliance should not be placed on disks or reels for producing flat rolls. A flangeless take-up with a weighted undercut roller resting on the periphery of the roll will insure tight and flat rolls. Any rollers should turn freely and move in synchronism with the film so that no relative motion takes place between the two. Telescoping of a roll should be carefully avoided as this causes transverse scratches.

(*3*) *Tensioning Devices.*—Theoretically the tension at any part of the film strand during winding should be constant but this condition is difficult to attain. When handling large rolls (1000 to 2000 feet) the strain in the region of the core is very great and cinching or sliding of one convolution over the adjacent one will occur, resulting in scratches unless the roll is wound tightly. The use of large cores (2 to 5 inches in diameter) is recommended, and the tension can be graduated during winding by means of a brake being controlled by the position of the weighted roller riding on the film roll.

(*4*) *Motor-Driven Rewinds.*[2]—These insure a more uniform tension on the film during winding but the maximum speed should be limited in order to minimize cinching.

(*5*) *Cleaning Attachments.*—The simplest cleaning device is a piece of lintless short nap silk plush (with non-raveling edge) held in the hand. The plush should be vacuum cleaned after each use and dry

cleaned at frequent intervals. A pneumatic device for removing dust, as used in the automatic type of Bell & Howell printer, is very effective.

(6) *Cleaning Fluids.*[3]—The most satisfactory liquids are carbon tetrachloride and light petroleum solvents. The great advantage of carbon tetrachloride is its non-inflammability although it is somewhat toxic and must be free from sulfur compounds, otherwise they will affect the silver image. With some individuals, tetrachloride may cause skin irritation especially in the presence of excessive perspiration. A mixture of petroleum solvent with enough tetrachloride to reduce the flash point to a safe margin is often used. If the dew-point of the air is relatively high, with rapidly evaporating solvents, moisture spots are apt to condense on the film, causing glossy spots on the wound roll.

(7) *Splicing Equipment.*—Commercial machines are effective but the splicing operation is a very obvious source of dirt. Extreme housekeeping precautions must be taken by the operator to insure that dirt and particles formed during scraping and cementing do not remain on the film.

(8) *An Enclosed Rewind.*—Archival films may be subjected to the following manipulations:

(*a*) Removal of rolls from the cold-storage vault and subsequent "tempering" to raise the temperature to insure that no condensation occurs when the container is opened.

(*b*) Inspection (on rewinds) for general condition of film or to isolate certain scenes.

(*c*) Rewinding of inspected rolls.

(*d*) Rewinding after printing.

Operations (*c*) and (*d*) should be conducted with a fully enclosed rewind which should be fitted with pressure air nozzles where the film leaves the cabinet while carefully filtered air is supplied to the air inlet. The enclosing cabinet should be made largely of glass to permit of full visibility of the contents.

Operation (*b*) is most conveniently carried out in the open and reliance must be placed on the succeeding rewinding operation to remove any accumulated dirt. However, the dirt could be removed by the insertion of a pneumatic dust-removing device placed ahead of the take-up. This, however, will cause scratches if cinching occurs. A minimum of dirt accumulation can be insured by rigid housekeeping.

The operator should handle the film gently only by the edges and should not "cup" the film by squeezing, otherwise in the case of brittle film this would cause longitudinal cracks.

In the printing operation or any operation where repeated rewindings are necessary, it is desirable to handle the film in loop form in an enclosed cabinet. This will reduce scratching to a minimum.

Adequate ventilation should be provided when handling cleaning solvents, and it is desirable to equip an air exhaust near the center and on the under side of the rewinding table to remove toxic vapors.

(II) SAFE AND ECONOMICAL STORAGE

In a paper presented at the Spring 1937 Meeting of the Society of Motion Picture Engineers (discussed again at the Fall Meeting) it was announced that The National Archives was making experiments on film-storage cabinets designed to offer reasonable safety at reasonable cost.[4] Two types of cabinets were discussed, both involving horizontal storage in shower-proof vented containers:

(*1*) Vertical water pipe in the rear, slitted and so arranged that water (released by a thermostat) would spray locally on the top of each can.

(*2*) Cascade type so arranged that water from a single source (sprinkler head), falling on the uppermost container, would cascade back and forth and downward until all the containers would be covered.

In brief, the first design offered reasonable safety but the cost was excessive—the actuating agent being the expensive item. The second design could be constructed cheaply, and it offered reasonable safety purely from a fire-control standpoint, but there was evidence of overheating of the unburned films in excess of what is considered good practice in terms of chemical preservation. The overheating resulted from two causes: (*1*) the column of heat enveloped all the cans before it reached the water sprinkler, and (*2*) the delay before the sprinkler head operated plus the delay in the cascading water reaching the affected container. Both designs depended upon a positive flow of water within fifteen or twenty seconds after ignition took place.

Cascade Type Cabinet

The first problem in improving the cascade type cabinet was to divert the heat away from the unaffected containers. This was accomplished by making solid shelves (uninsulated in this instance) so that the compartments so formed opened into a common vertical flue.

The water sprinkler was then placed at the top of the flue directly in the path of the escaping heat. Finally, provision had to be made for diverting the water into the compartments. This was done by a water carrier located approximately one-fourth of an inch below the ceiling of the compartment and containing a hole directly over the center of the container. The rear end of the carrier extends into the flue forming a flange. The water, picked up by this flange, is then carried into the compartment and falls on the top of the container.[5]

A further precaution was taken in the use of baffles, one of which is called a floodgate, extending up from the bottom of the compartment in the rear, and the other extending down from the top. The overlapping of these baffles reduces direct radiation from the heat in the flue. The lower baffle forms a puddle of water around the bottom of the container. This cabinet is illustrated in Figs. 1 and 2.

The essential features of this cabinet summarized are:

(*1*) Solid shelves between compartments.

(*2*) Flanges extending into a vertical flue.

(*3*) Water carriers with holes in the center to permit the water to fall on the containers.

(*4*) Floodgates which form pools of water around the lower part of the containers and seal the apertures opening into the flue.

(*5*) Overlapping baffles to reduce radiation from the flue.

(*6*) A water sprinkler.

(*7*) Direct and immediate application of water to all compartments.

(*8*) Secondary application of water as a result of the cascade principle.

(*9*) Dilution of toxic fumes by spray from sprinkler.

(*10*) Removable shelves for easy cleaning and repair.

Extensive experiments were conducted with this cabinet, the final tests and measurements being made at the National Bureau of Standards. The tests were of two general kinds: (*1*) Internal (heat exposure inside the cabinet) and (*2*) External (heat exposure outside the cabinet).

Internal Heat.—Nitrocellulose film was placed in each of the twenty compartments and various units *inside* the cabinet were ignited in various combinations in order to determine whether or not such a fire would spread. A standard "heat-collector" type, 165°F water-sprinkler was used to furnish a 20-lb flow pressure. Both thermocouples and maximum reading thermometers were used to determine the temperatures generated at various points inside the cabinet. Ignition was induced by ordinary heating coils.

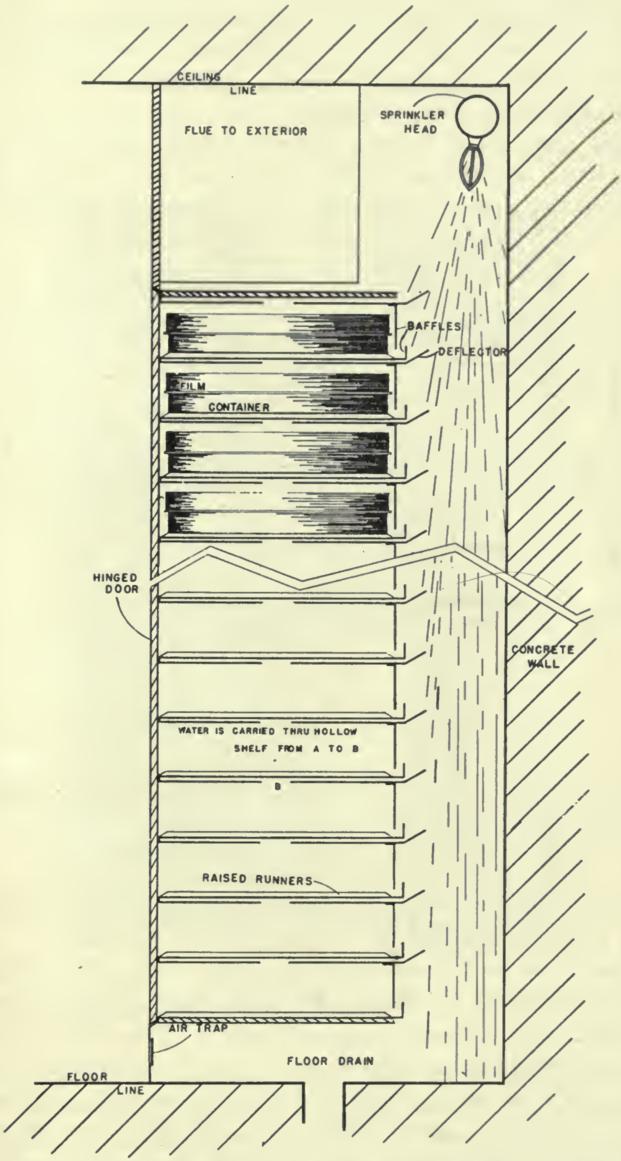

FIG. 1. "Cascade" type of film storage cabinet developed by The National Archives.

Under the conditions described above the cabinet seemed to meet all the requirements for safe and economical storage of motion picture film. Not only was the fire successfully confined to its original source but there was no apparent damage to adjacent film from water or excessive heat (see Figs. 3 and 4).

External Heat.—The factors of film distribution, water supply, sprinkler head, and thermocouples (ten in all) were similar to those described in the tests with *internal* heat. However, combustion was

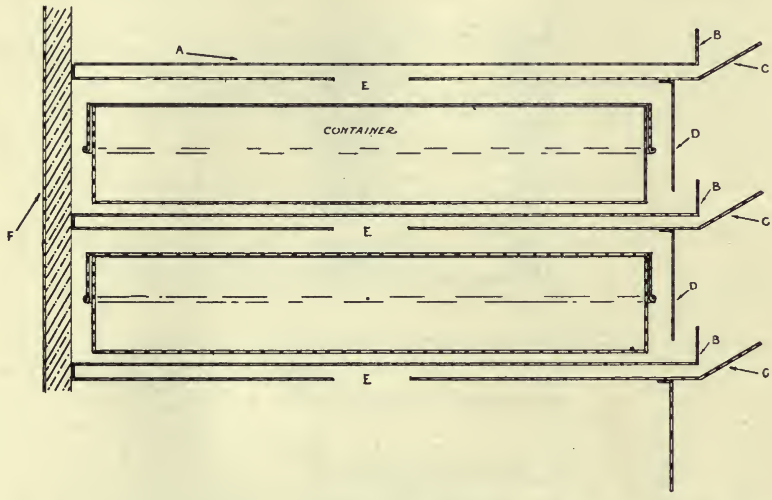

FIG. 2. Detail of "cascade" film-storage cabinet. *A*, sheet metal forming floor of compartment. *B*, floodgate baffle. *C*, divergence flange and water carrier. *D*, baffle. *E*, hole through which water falls on container. *F*, door for 10 compartment section.

generated *outside* the cabinet inside a cubicle to simulate conditions found in a burning building.

The cubicle referred to was made of hollow tile and brick and contained 275 cubic-feet of space, a suitable vent, an observation window, a door, and a draft opening near the floor. The combustible contents of the room totaled 1375 lb, or an average of 50 lb per square-foot of gross floor area. The maximum temperature in the room (outside the cabinet) was 1495°F. The highest temperature observed *inside the cabinet proper* (*i. e.*, within the compartments) was 148°F, but the average was well under this reading with a wide safety margin. The temperature record of this test is given in Fig. 5. The

conditions before and after this test are illustrated in Figs. 6 and 7. No film was ignited and there was no evidence of damage from water or overheating.

Insulated Puddle Type Cabinet

In experimenting with various types of cascade cabinets it was discovered that in many instances there was no spread of fire even when

FIG. 3. Showing volume of water in "cascade" type of cabinet during operation of sprinkler head under a 20-pound flow pressure.

the sprinkler failed to operate, particularly in the absence of flame. This prompted further thought to insulation as a safeguard in case the water supply failed, whereupon insulated shelves were constructed of sheet asbestos $^3/_8$ inch thick, sheathed between two pieces of metal. The compartments so formed opened directly into the flue. It was necessary, however, to prevent direct radiation from the flue by the

use of baffles previously described. By bending the lower baffle (corresponding to the floodgate in the cascade cabinet) at an angle into the flue, it served the additional function of a deflecting flange. Thus this cabinet closely approximates the cascade cabinet except that the water is not carried to the top of the container, and it is insulated. This cabinet is illustrated in Figs. 8 and 9.

FIG. 4. Showing results of fire test on "cascade" type of cabinet. Not only was fire confined to its original source but adjacent film was undamaged from water or heat.

Experiments on this cabinet are incomplete and its full possibilities have not as yet been explored. However, it is believed that its safety characteristics compare favorably to those of the cascade type.

The conclusions set forth herein are based on the use of the container designed by The National Archives, but it is believed that any heavy, vented container (shower-proof for the cascade type cabinet)

would prove satisfactory. Additional weight or thickness tends to retard the rise of temperature, and is, therefore, an advantage. The soldered heat-collector type of sprinkler head operated more rapidly than the others tested, and is, therefore, recommended.

In order to provide a cabinet at reasonable cost, simplicity in construction design has been religiously observed. In the cascade type

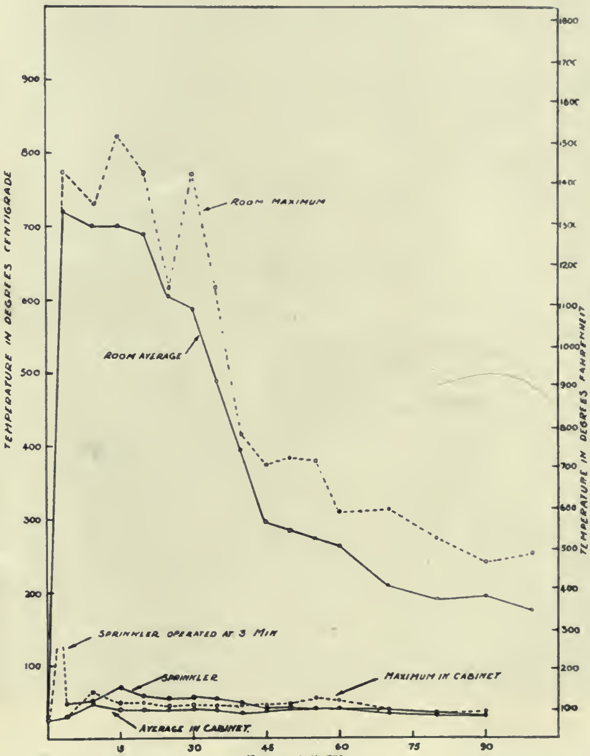

FIG. 5. Results of test illustrated in Figs. 6 and 7; fire exposure test of film cabinet, July 13, 1938.

of cabinet two sheets of galvanized iron were used to form the shelf, each about twelve inches wide and fourteen inches long (see Fig. 2). The rear end of the upper sheet (A) is turned upward at a right angle to form floodgate (B) and serve as a baffle. The rear end of the lower sheet extends into the flue and upward at any convenient angle to form a deflecting flange (C). A third sheet, bent at a right angle, is

spot-welded to the second (or lower) sheet to form one of the baffles (*D*). A hole (*E*) is stamped in the center of the second sheet to admit water. Additional construction involves insulated side walls, means for supporting the shelves, and doors. In a six-foot cabinet contain-

FIG. 6. Inside view of cubicle in which "cascade" type of cabinet was tested with external heat. *A*, observation port. *B*, combustibles. *C*, side view of cabinet with door closed.

ing twenty compartments, two sections and two doors are recommended.

In the puddle type cabinet (see Fig. 9) two sheets of metal are used as before to form a shelf, but with insulation between them. The rear end of the upper sheet is turned upward (*C*) into the flue and serves three purposes: (*1*) as a diverting flange, (*2*) as a floodgate to form a puddle (*D*), and (*3*) as one of the baffles. The rear end of

the lower sheet (B) is turned downward to form the upper baffle. (A) represents the container.

In both types of cabinet the container (Fig. 10) is held slightly above the bottom of the compartment by means of rods (B) to reduce

FIG. 7. Showing "cascade" cabinet after external heat test. This represents the appearance of the cabinet after sixty-six internal fires and two external fires, the last of which was continued for twenty-four hours. No film was ignited.

the area of contact of metal against metal and to provide additional insulation. Cabinet design is of great importance because by making it approximately air-tight and providing only a small breather vent in the base of each stack, the probability of the combustion taking the form of flame is reduced to a minimum. This type of cabinet may be designed to be built into new construction at very small cost. In this case the concrete wall, floor, and ceiling will form the back, bottom,

and top of the cabinet, leaving only the two sides and doors to be installed. The sides of adjacent stacks may be common (if desired), reducing the construction to one side and the door for each stack. The vertical partitions should preferably be insulated as an additional precaution to prevent communication of fire from one stack to another in the event of failure of the sprinkler system. These may be erected with considerable facility and little cost, leaving only the shelves to be inserted in the guides provided.

This construction offers the additional advantage of being highly accessible for cleaning, painting, or replacement. The shelves being easily removable, all interior surfaces can be exposed in a few minutes' time. It would thus be entirely practicable to clean and paint at suitable intervals, which would make the use of expensive corrosion-resistant metal unnecessary. It should be pointed out that with the system proposed there is no damage from water to the unaffected film. In other words, the protection is complete and covers both the structure and the materials stored. Furthermore, sprinklers operate only in the affected stack, and with proper construction there should be practically no fumes within the vault. This feature greatly decreases the hazards to health and life.

Obviously a cabinet could be built in a number of ways and still retain the essential features of either type described. The studies involved nearly a dozen designs and adaptations, and the experiments numbered well over a hundred. The design and features herein reported seem to have the greatest merit in terms of the objective set up at the beginning of this paper.*

To summarize briefly, the advantages of this general type of storage equipment and particularly of the cascade type cabinet seem to be:

(*1*) Complete protection to the building and adjacent structures.

(*2*) Complete protection to all film not originally involved in a fire. This includes protection from water as well as from fire.

(*3*) Protection of the health of personnel engaged in handling film by removing the products of slow decomposition and removing and isolating the products of combustion.

(*4*) Comparatively low first cost.

(*5*) Accessibility for repair and maintenance.

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* The cabinet referred to in the foregoing discussion was patented by John G. Bradley on February 13, 1940, under the Act of March 3, 1883, as amended.

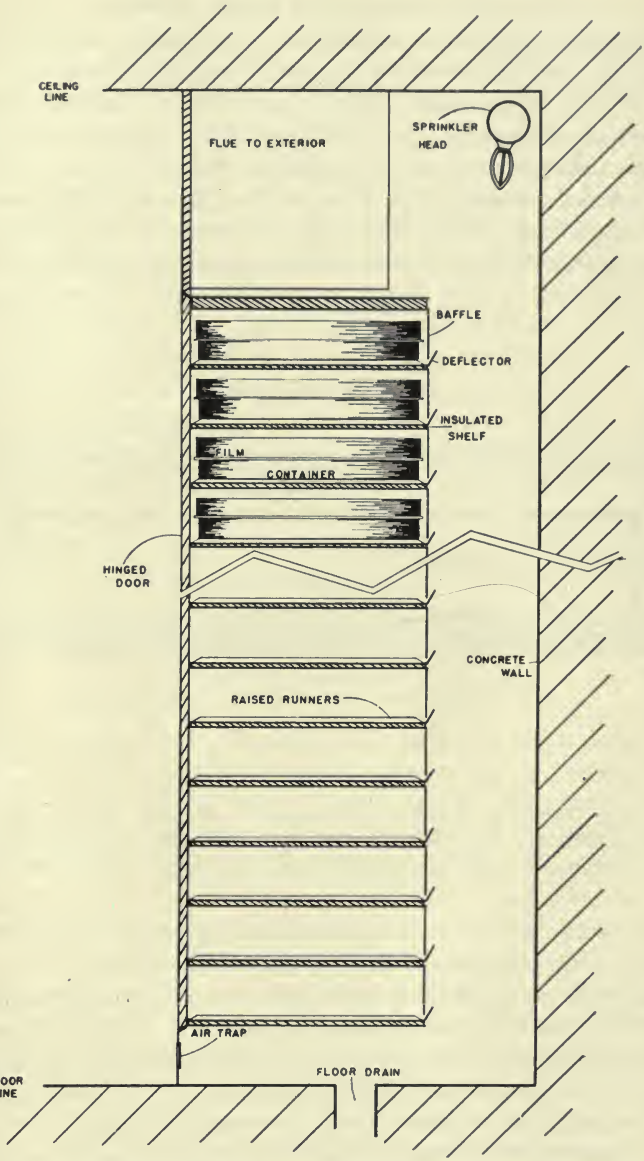

FIG. 8. "Puddle" type of insulated film storage cabinet as developed by The National Archives. Experiments with this design are incomplete.

Vent Size per Unit Weight of Film

The experimental film container as originally designed by The National Archives contained $^7/_{10}$ sq-in vent area for 1 reel (5 lb) of film. This is equivalent to 14 sq-in per 100 lb of film. This ratio was based upon standards then existing and still contained in most of the literature governing the storage of nitrocellulose film.

When this container was tested at the National Bureau of Standards before the SMPE Committee on Preservation of Film, it was noted that the lid warped materially, indicating insufficient vent area.

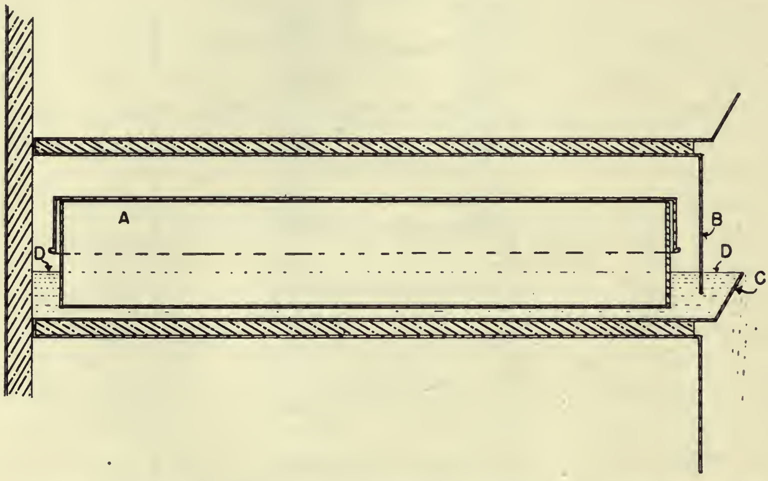

FIG. 9. Detail of "puddle" type insulated cabinet. *A*, the container in storage position. *B*, baffle. *C*, combination of baffle, floodgate, and divergence flange. *D*, puddle of water formed around lower part of container.

On recommendation of the Committee this area was increased to 1 sq-in. This is in ratio of 20 sq-in per 100 lb of film.

Relatively recently there have been two or three serious film fires in different parts of the country that resulted in the development of excessive pressures. The experience with the container plus the fires just referred to have led to a reconsideration of the entire question of vent area per unit of film weight. Consequently, Mr. James E. Gibson, Laboratory Technician, Division of Motion Pictures and Sound Recordings of The National Archives, was detailed to the National Bureau of Standards where an original research project on this subject was undertaken. The studies were conducted along three lines:

(*1*) taking the amount of film and the size of the container as constants and the vent area as the variable, (*2*) taking the vent and the container as constants with the amount of film as the variable, and (*3*) taking the vent and the amount of film as constants and the size of the container as the variable. The sizes of the containers ranged from 197 cu-in to 38,016 cu-in or 22 cu-ft. The amount of film ranged from 8 oz to 30 lb. A very satisfactory correlation was noted in the results obtained. The values for pressures plotted against the ratio of film to vent area formed a regular curve. The pressure rises slowly with increase in the ratio of film to vent area until a critical point is reached, above which the curve rapidly approaches the vertical. Beyond this point a slight increase in the amount of film or a slight decrease in the vent area will result in explosive pressures.

In the studies referred to it was found that 6 lb of raw film per sq-in of vent area represent a critical point above which there is danger of explosions. In view of these experiments The National Archives reiterates its recommendation of 20 sq-in of vent area per 100 lb of film in standard vault construction. It should be noted that this discussion is based on the use of unenclosed films and on preliminary data furnished by the National Bureau of Standards. A final and detailed report is to be issued shortly by that agency.

(III) PRINTERS FOR OLD AND SHRUNKEN FILM

Hitherto there has not been much demand for the reproduction of films which were too old and shrunken to pass through an ordinary printer. It is true that at various times old films have been reproduced for various commercial purposes, both by optical[6] and by step printers,[7] but the problem did not assume a serious aspect until the use of old films for museum and archival study and research purposes became as significant as it is today.

With the advent of sound, modern film processing became a much more precise procedure than it was in the old days before rigid standards[8] for film dimensions were established. The present trend in film printing has been for the elimination of the old style step or intermittent printer and to substitute for it the much speedier and more precisely constructed continuous printer.[9] However, the step printer had an advantage which the continuous printer does not have. As each frame was printed step by step in the intermittent printer any minute deviation[10] of the negative was independently corrected on the copy by a slight shifting of the relation between the negative and

the copy film. This correcting shift took place during the period when the printing light was cut off by the shutter and the exposure of the copy film took place subsequent to the correcting shift between the two films. As long as the tolerance of the printer permitted the shrunken negative film to run over the sprockets and to be pulled down by the intermittent mechanism, the resulting print was quite satisfactory for silent projection. Old style step printers are still used to a limited extent for certain purposes, such as the making of master or duplicating prints and for background transparencies,[11] but even when so used they are usually rebuilt for greater accuracy so that they are

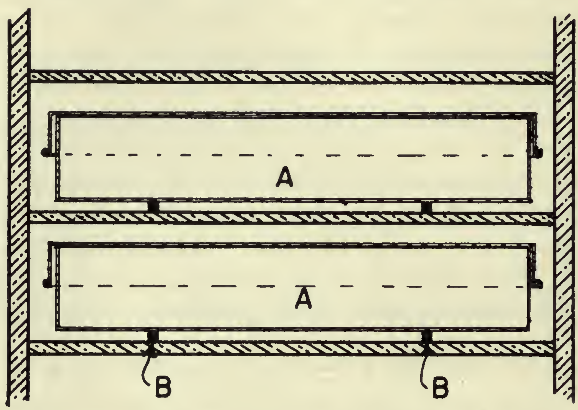

FIG. 10. Showing position of container (*A*) above floor of compartment, accomplished by use of support rods (*B*).

seldom suitable for films having more than a slight shrinkage. Even an old style step printer can not be used for printing badly shrunken films, because there is a very definite limit to the shrinkage which its tolerance limit can accept. Other disadvantages in step printers consist in the variations from old standards which are found in modern sound projectors.

The modern sound projector requires a smaller image or frame in order to allow for the sound-track. A sound projector can be made convertible for silent pictures, but in most cases convertible projectors are not to be found when a silent print is to be run. It is desirable, therefore, in most cases to reproduce an old film to the new standard if its use is not to be very much limited. Not only is the frame size of the present-day standard smaller, but the number of

frames per second of projection is 24 instead of 16. Unless extra frames are interpolated to convert the silent film to sound speed, the tempo of the action becomes too fast to be natural. It is not possible to introduce these extra frames when using an ordinary step printer. No doubt a step printer mechanism which would add the interpolated frames could be designed, but this would not solve the problem of reducing the frame size without losing a considerable portion of the image within the frame taken up by the sound-track and the wider frame line.

The obvious solution of the problem is an optical printer especially designed to take care of the contraction of the shrunken film from standard size. This requires more than an ordinary optical reduction printer such as is used for making 16-mm reduction prints from 35-mm negative.[12] Such an optical printer would have to be a modified form of trick optical printer such as is used for process photography.

There are two general types of trick optical printers. one which uses direct optical methods only,[13] and a second type in which the image is projected upon a translucent screen and rephotographed by a camera on the other side.[14] The second type has no advantages over the first for our purpose and is much more cumbersome and bulky than the first type.

The direct optical printer is essentially a small projector adapted to project very small images directly upon the virgin film in a lensless camera.[15] For accuracy the projector, the projector lens, and the camera are all adjustably mounted in line on a light-bench. Such a light-bench is most economically and accurately made from a lathe bed. Often the other parts of the lathe can be utilized for parts of the apparatus. After the removal of the upper part of the headstock the camera is mounted thereon. The tailstock base can be used to mount the projector lens which must be a photographic objective, preferably of four to six inches in focal length and of very good definition.[16] For this purpose the tailstock is removed from the right end of the lathe and placed between the headstock camera mount and the lathe saddle. The lathe saddle is run toward the right end of the lathe and used as the mount for the projector head and lamp house(Fig. 11).

The lamp house can be quite small, as a single 6-volt head-light lamp will furnish ample illumination. Adjustment for positioning the lamp in relation to the condenser and film aperture is necessary.

The lamp house should be ventilated and reasonably light-tight. For control of the light intensity the lamp may be connected to a 6-volt storage-battery through a sensitive graduated rheostat and a large, finely calibrated voltmeter. As the camera mount is the control end of the machine, the rheostat and voltmeter should be mounted on a small switchboard placed at or near the camera end of the machine. A flexible lamp cord connects the lamp to the instruments on the control board and to the battery.

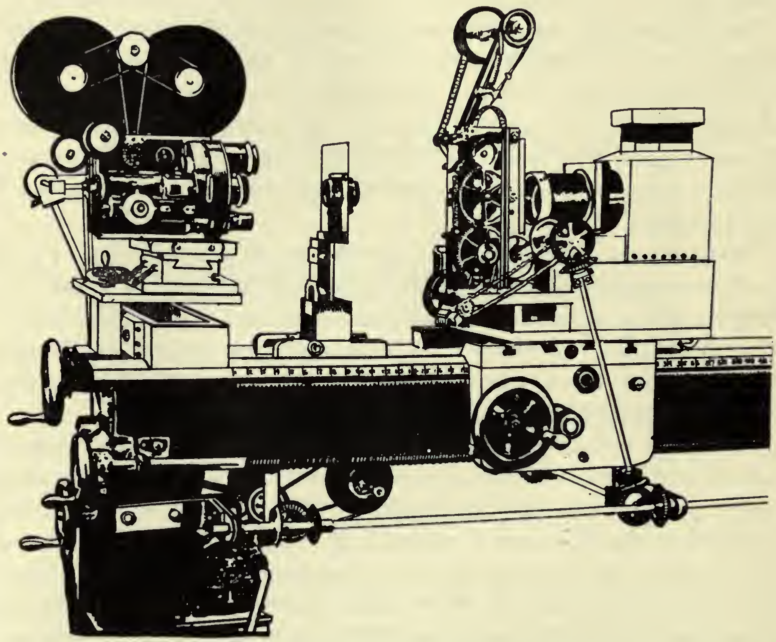

FIG. 11. Optical printer for old and shrunken films as designed by Carl Louis Gregory, The National Archives.

The line-up of the component parts of the machine must be very accurate. An imaginary line parallel to the lathe bed and passing through the optical axis of the projection lens determines the positions of the camera, the projection head, the condenser, and the lamp filament, as well as the projection lens. The center of the camera picture aperture must be at right angles to the optical axis with its intersection at the center of the frame; the objective axis coincides with the optical axis of the machine as above stated; the projection head aperture meets the axis at its center and at right angles; the optical

axis of the condenser system coincides with the general axis, and the lamp filament, which must be of small dimension, has its center also on the general axis.

When these conditions are met, a film placed in the projector head can be focused directly on the film in the camera, and by suitable adjustment of the component members of the assembly, the image on the copy film in the camera can be adjusted to any desired proportion of frame size.

These are the essential primary conditions for a direct optical trick printer, so that when the necessary changes are made to permit the projector head to function with shrunken film, the machine can reproduce not only badly distorted film, but it can be used also for an infinite variety of effects such as fades, dissolves, wipes, swishes, multiple exposure, mask work, and many other kinds of process photography.

The changes in the projector head, to make it able to accommodate shrunken film, are not many. The feed and take-up sprockets must be made easily interchangeable with other sprockets which will accommodate shrunken film. The side guides of the gate can be spring-mounted on one side so that whatever variation occurs in the film width, the opposite side guide will meet the opposite edge of the film and eliminate side weave.

The best intermittent movement for this type of machine is the finger or pin draw-down such as was usually employed in the older types of cameras and step printers. Any type of round cam or bell-crank intermittent movement can easily be altered so that a slight shift of the cam or crank on its drive axis will change the throw of the pins to fit any degree of contraction between the perforations. Those types having a harmonic cam can have an adjustable circular cam substituted. Change from a harmonic cam to a circular cam changes the relation of the pull-down period to the rest period. The decrease in the rest period is not a disadvantage, because the slow pull-down is more suitable for gentle transport of brittle film, and makes for greater accuracy in registration. Any decrease in exposure time is easily compensated by a slight increase in the lamp brilliancy by use of the rheostat control.

Pilot pin registration for shrunken film is not considered practical. Pilot pin registration requires that the perforations be exactly uniform and that the pilot pin fit each perforation exactly. While it is theoretically possible to make spring pilots with rigid positioning in

two directions, such a provision would not take care of damaged sprocket-holes. With slow operation and gentle spring pressure in the gate, the film will have sufficiently good registration, unless both sprocket-holes engaged by the draw-down pins are damaged.

Unless a large proportion of the sprocket-holes are damaged, these alterations in the projector head will take care of almost any shrunken film that has enough tensile strength to be run through the machine. Even very brittle film can often be conditioned and certain repairs made before insertion in the machine. The conditioning of old film is a subject in itself and will not be considered here.

It is assumed that the projector head has an adjustment for a slight amount of framing. This adjustment needs to be only enough to take care of off-standard frame line or less than a quarter of an inch, so that the picture can be threaded in frame. Of course the old film must previously be inspected and all misframes removed before duplication. Off-standard frame line is automatically transformed to standard in the camera, as the frame line of the copy depends on the camera mechanism.

Partial discolorations in the image of the old film can be almost entirely eliminated in the optical printer by using modern duplicating stock or panchromatic copy film and suitable filters between the lamp house and the projector head.[17] Generally speaking, this requires a filter the color of which is nearly complementary to that of the discolored image. Where the image has partially faded, other treatment, such as chemical restoration of the image, may have to be used. Emulsion stains, on the other hand, require filters of the same color as the stain.

Very often considerable improvement in the quality of the image may be obtained by optical copying. It is very easy to increase contrast in flat images or to reduce contrast in harsh films by suitable choice of copy film and controlled development. On the other hand, scratches and abrasions on the film are likely to be accentuated. Cleaning with carbon tetrachloride will often help to clear up dirt and adherent imperfections, and varnishing with clear varnish which does not contain celluloid or gelatine solvents will fill up scratches to a considerable extent.

Details of the interconnections between the camera and the projector movements and the varied arrangements for the different adjustments do not need to be given here. Special optical printers are usually made to order and designed to perform certain special func-

tions. Almost any mechanical shop accustomed to the building of motion picture apparatus can construct a suitable machine for the optical reproduction of old and shrunken films.

The mere possession of such a machine does not alone solve the problem. At least one highly skilled operator must be trained to operate the machine. Besides the mechanical dexterity required for operation, a wide range of photographic knowledge is required in order to be able to choose the particular types of emulsion which will give the best results and to process the copies after exposure.

Most old films requiring rectification and reproduction are silent films taken at the rate of 16 per second; these may be "stretched" to 24 frames per second by repeating the exposure of alternate frames of the original in the camera, so that each foot of the original film results in a foot and a half or 24 frames of copy film. Also, the image size is reduced to fit the sound frame aperture of the copy camera.

This brief survey of printers for the reproduction of old and shrunken films has dealt with the problem of printing copies for preservation. It would take a respectably sized volume to go into detail covering all the minutiae which deal with printer design and use, without even touching upon the various physical, chemical, and mechanical treatments which might prove of value in the restoration of the images on old and shrunken film to render it more suitable for reproductive processes.

The Committee feels that the adoption of the standards and practices as set forth in this report would give additional insurance against natural losses of wear and tear generally sustained in handling of film as well as losses from deterioration and fire in the storage of film The interest in printers for old film is less wide-spread than that found in the other subjects discussed. Nevertheless, since such equipment does have an important application in the ultimate *perpetuation* of film records, the Committee has submitted it for reference, and invites constructive criticism.

J. G. BRADLEY, *Chairman*

J. E. ABBOTT	R. EVANS	T. RAMSAYE
J. I. CRABTREE	M. E. GILLETTE	V. B. SEASE
A. S. DICKINSON	C. L. GREGORY	W. A. SCHMIDT

[This report was originally prepared in 1939 by the Committee listed above. and revised by the present Committee for presentation at the 1940 Fall Meeting at Hollywood, Calif.]

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REPORT OF THE STUDIO LIGHTING COMMITTEE*

Summary.—*A brief description of the changes that have occurred in studio lighting during the past season. No important changes of technic have occurred but there have been a number of changes in lighting facilities.*

It is the purpose of the Studio Lighting Committee to keep the Society informed as to the changes which from time to time occur in the lighting technic, and changes or improvements in lighting equipment. The Committee has attempted also to keep the Society informed of new and immediately anticipated developments in technic and equipment which indicate possibilities of potential advantage for photographic lighting.

Since the Spring Convention at Atlantic City we report no important changes of lighting technic, but with respect to lighting facilities there are a number of matters that should be brought to your attention.

The 5-kw *T-64* has been well accepted. This bulb, being applicable in the 5-kw Solarspot equipment, has found wide application in studios well supplied with that type of lamp. The *G-64* 5-kw globe is used principally with the old 24-inch Sunspot equipment, the design of which was not as well adapted to the *T* type of bulb. More recently the manufacturers of tungsten filament globes have introduced the 2-kw *T-48*, which has all the advantages of less blackening, no blistering, and hence the longer useful life which the 5-kw tubular globe of similar design affords.

One lamp manufacturer has completely redesigned his 500-watt, 2000-watt, and 5000-watt Solarspot equipment. The new-style Solarspot affords greatly increased ventilation in all positions in which such equipment is used. Since the lamp manufacturers have so perfected the design of bipost globes that they are practically prefocusing, the new Solarspots are made front-opening to afford the most convenient and accessible means of installing globes and the special filters required for Technicolor photography. The new style Solarspots incorporate quick focusing arrangements, conveniently accessible from

* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 22, 1940.

either the front or the rear of the lampheads. A number of other minor improvements contribute to convenience in operation and longer life of the equipment.

The tiny spotlamps of 100 and 150-watt sizes have, with the application of fast emulsions, found a definite place in industry. Their small size permits them to be mounted on cameras for use as catch lights, and because they may be easily concealed behind set pieces they afford a convenient means of providing touches of light here and there as needed.

Some experimental Solarspot equipment has been designed to accommodate the 10-kw *G-96* tungsten filament globe. These Super-Solarspots, equipped with Macbeth whiter-light filters, have been experimentally applied in Technicolor photographic operations. The acceptance of equipment of this type is being watched with interest to ascertain just what place it may hold in the future as a lighting source for color photography.

High-intensity arc spots continue to be the principal light-sources for color photography. Improvements in negative carbons have greatly restricted the so-called "frying noises," so that it is no longer a serious detriment in sound recording. Further improvements have been made in the arc equipment through the application of shear-rubber mountings to the mechanism-driving motors, and most of the older arc equipment has been brought up to the present standards by revision.

There are a number of items of interest in certain special fields of photographic illumination. At one of the major studios a short subject was made, which exhibited the startling photographic possibilities of the Edgerton high-speed mercury lamp, which is capable of photographing still pictures in approximately $^1/_{130,000}$ of a second, and motion pictures, at a thousand frames per second. While such light-sources have been known to the industry for some time, we believe that the making of this short subject was the first production, involving such illumination, designed primarily for public exhibition.

There has been considerable interest among the process photographers in the experimentation with a 10-kw biplane filament lamp. This concentrated tungsten filament source, when used with plano-convex condensers and *f*/3.6 objective lenses, is said to produce an illumination of 45 foot-candles over an 18-foot screen, which is an increase of 50 per cent over the results previously obtained with the 7-kw globe. It is anticipated that the results of this experimentation

will produce a continually greater use of these high-wattage, concentrated-filament globes in the process slide projectors.

The process projection of motion picture backgrounds has profited much from the series of conferences held during the Summer of 1939 under the auspices of the Research Council of the Academy of Motion Picture Arts and Sciences. One company, in close conformity to the suggested specifications of the Research Council Rear Projection Committee, has produced a high-intensity arc mechanism control and lamp house. This new equipment makes possible the transition from one carbon size to another with only momentary delay as positive carbons are positioned through an automatically operating photronic control. The negative carbon can be maintained at any given arc voltage automatically when adjusted by the control of a single governing rheostat. The new lamp has been designed to accommodate carbons from 13.6 to 16 and 18 mm in diameter, with their various negative carbons, and the control arrangements will maintain positive and negative carbon positions automatically at the proper burning rates. The positive feed is water cooled. The lamp is extremely convenient for operation, and with this new high-intensity arc and the potentialities of the relay condenser system, along with the many improvements that have been made in the projector head, the possibilities of background projection have been considerably augmented.

E. C. RICHARDSON, *Chairman*

F. E. CARLSON R. E. FARNHAM C. W. HANDLEY
F. M. FALGE D. B. JOY

REPORT OF THE COMMITTEE ON NON-THEATRICAL EQUIPMENT*

Summary.—*Among the problems facing the Committee this year is the preparation of a list of performance criteria covering the important functions of 16-mm projection equipment, both silent and sound. The Committee has arranged in this respect to coöperate with the Committee on Scientific Aids to Learning, of the National Research Council, in preparing a report to guide the educational field in the selection and use of this equipment.*

The legitimate field of interest of the Non-Theatrical Equipment Committee covers a range of subjects which, in their 35-mm aspects, occupy the attention of at least five of the Society's other committees. As a consequence, one of the most difficult of the problems of the Committee is the selection of those projects on which it can most usefully spend its time.

In considering this problem the present Chairman was fortunate in having had presented a definite request for coöperation from the *Committee on Scientific Aids to Learning* of the National Research Council, of which Dr. Irvin Stewart is chairman. This committee has for several years been carrying on a study of the use of 16-mm projection equipment in schools and colleges, with a view to preparing reports to guide the educational field in the selection and use of this equipment.

After careful consideration of this request and several conferences between the Chairman, Dr. Stewart, and the Engineering Vice-President of the Society, the Chairman has proposed to the Non-Theatrical Committee, and the Committee has decided to undertake, the preparation of a list of *performance criteria* covering the important functions of 16-mm projection equipment, both silent and sound. This list will cover such topics as steadiness of projected picture, sharpness of screen image, quantity and distribution of screen illumination in relation to power of light-source, reasonable expectation of film life, freedom from excessive heat effects, steadiness of film motion in sound-reproducing mechanisms, frequency characteristics of re-

* Presented at the 1940 Fall Meeting at Hollywood, Calif.; received October 19, 1940.

produced sound, amplifier power, background noise level of equipment, *etc.* In addition, performance criteria for screens will be investigated and specifications given for equipment installations in various sizes of rooms.

The purpose is to provide an impartial composite portrayal of the performance that may reasonably be expected at the present time from good 16-mm projection equipment, expressed so far as possible in terms that admit of definite quantitative measurement. The project obviously involves, in many instances, the specifying of the method of measurement, and, in other instances, the classifying of equipment in relation to factors such that the requirements differ with the conditions of use, and also where the factor of cost has a controlling effect.

A list of performance criteria such as is proposed will be valuable to the educational world as a guide to the selection of equipment for specific purposes, and it will also serve to indicate when equipment is in need of repair or adjustment, and when it is obsolete. At the same time this study can not fail to be helpful to manufacturers by indicating those points of performance which may most advantageously be improved, as well as by laying a foundation for better understanding between the manufacturer and the user of equipment.

Fortunately, the present Committee is well qualified to carry on such a study, since it includes directly among its members men who have specialized knowledge of all the topics mentioned above. It is hoped that by the time of the next convention of the Society, the work will have progressed far enough to permit the presentation of a detailed report on this project.

A second project which has been referred to the Non-Theatrical Committee by the Standards Committee is a study of 16-mm and 8-mm sprocket design, with a view to possible revision of the recommended practices of the Society covering these sizes of sprockets.

J. A. MAURER, *Chairman*

J. G. BLACK	J. A. HAMMOND	R. F. MITCHELL
F. E. CARLSON	M. HOBART	L. T. SACHTLEBEN
N. B. GREEN	R. C. HOLSLAG	A. SHAPIRO
F. M. HALL	R. KINGSLAKE	M. G. TOWNSLEY
	L. R. MARTIN	

REPORT OF THE MUSEUM COMMITTEE*

***Summary.**—The Committee is endeavoring to augment the motion picture exhibit at the National Museum of the Smithsonian Institution at Washington, which the Board of Governors has chosen as the official museum for historical exhibits collected by the Society.*

A complete list of motion picture exhibits at the Museum is given, and a plea is made for assistance by the members of the Society in adding to the accessions.

A previous committee was successful in obtaining a number of exhibits for deposit in the National Museum of the Smithsonian Institution in Washington, D. C., the official depository of the Society. Among the new exhibits obtained were notably those of Thomas Armat and C. Francis Jenkins. The complete exhibits of these two distinguished members of the Society and pioneers in the art have now been turned over to the National Museum.

The Committee Chairman has held two meetings with officials of the National Museum and jointly outlined a policy to be followed in obtaining future exhibits. The first and most important matter was to obtain a complete inventory of all material now on deposit in the National Museum Motion Picture Exhibit. This inventory has now been prepared and is attached hereto. The Committee especially desires that members of the Society who know of the existence of appropriate exhibit pieces advise us as to where they may be located. We are particularly anxious to obtain advice as to the location of an Edison "Peephole" mechanism.

Dr. Carl W. Mitman, Head Curator of Arts and Industries of the United States National Museum, has stated that if we can get a promise of sufficient new material he believes he can have additional space set aside in the National Museum to accommodate the exhibit. In this connection it is planned to build a fine, new Industrial Arts Building in the future development of Washington governmental buildings, to be located about one block from the National Museum. Space will be set aside for a motion picture exhibit if we can find the additional necessary material fully to represent the development of the motion picture art.

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It is noted that a number of small exhibits have been started by various private concerns associated with pioneer members of the Society. These private exhibits are viewed by only a limited number of persons and the Committee hopes that the owners can be persuaded to coöperate by sending this material to the National Museum, where it can be incorporated in the main SMPE collection for the benefit of the many thousands who visit Washington each year.

The National Museum has asked us to obtain the coöperation of the members of the Society familiar with early developments in the motion picture art in order that they might know what exhibits would be most desirable.

H. T. COWLING, *Chairman*

THOMAS ARMAT — HERBERT GRIFFIN

RAYMOND EVANS — O. B. DE PUE

F. H. RICHARDSON

ACCESSIONS RELATING TO THE INVENTION OF MOTION PICTURES IN THE UNITED STATES NATIONAL MUSEUM

Accession No.	Source	Material
88755	Mot. Pict. Prod. & Distr. Amer.	2 Edison motion picture cameras (motor driven), 1911
		1 Edison light-testing machine, with one motor, 1913–15
90393	E. H. Amet	3 Motion picture machines
		11 Samples of motion picture film, 1896–98
90396	Int. Mutoscope Reel Co.	1 Projector
		3 Cameras
		2 Magazines
92450	John U. Perkins	1 "Movee" camera and projector
94132	E. H. Amet	A small piece of early motion picture film: $3^1/_4 \times 4^1/_4$ negative of a model basin with miniature battle fleet in action, earliest utilization of models for full-size motion pictures
		1 news clipping from an 1898 newspaper relating to motion pictures
		1 business card, with a cut of the Magniscope, one of the early forms of motion picture apparatus

Accession No.	Source	Material
100180	Mary E. Trueman	13 Animated lantern slides
102921	Mot. Pict. Prod. & Distr. Amer.	1 Glass mirror screen
105044	C. Francis Jenkins	Radio movies receiver
106273	Mot. Pict. Prod. & Distr. Amer.	1 Synchronizer for Edison talking machine 1 Projector
110071	Eastman Kodak Co.	1 11 × 14 transparency showing steps in production of Kodachrome motion picture film
112261	Stanislaus Schneider	33 Pieces of early motion picture apparatus comprising cameras, projectors, film frames, printer, perforators
119335	John F. Daniel	1 Edison projecting Kinetoscope
124316	Eugene Augustine Lauste	21 Photos of Lauste's inventions in silent and sound motion pictures 1 Portrait of Mr. Lauste
126197	B. B. Heal	1 Motion picture camera, 1 tripod 1 Williamson perforator, 1 can containing 15 short pieces of film
127113	Francis Marsten	1 6-Inch strip of 35-mm film with perforations, bound in flexible metal
129430	Bell Telephone Laboratories	
	1—1908–9	Vibrating mirror records reconstructed with old parts
	2—1911–12	Microphone relay with double telephone, used by Lauste to amplify sound photo
	3—1910	Quadruplex telephone set, for testing sound-on-film
	4—1904–5	Acetylene gas light-valve
	5—1926	Compressed-air loud speaker, showing magnet with armature and comb valves, unfinished
	6—1908	Koenig flame recorder mirror, used in connection with recording sound from phonograph disk to film
	8—1910	Carbon microphone—used by Lauste in his early experiments

Accession No.	Source	Material
		in recording and reproducing sound-on-film
	7—1908	Koenig flame acoustic recording box—modified by Lauste, used in connection with recording sound from phonograph disk to film
	9—1913	Film-gate, used in connection with reproducing sound recorded by 3 to 1 revolving cylindrical lens
	10—1908	Light-valve recorder (iron hydroxide solution), original model
	11—	Two carbon ball microphones
	12—1913–14	Electrodiamagnetic double-ribbon recorder
	13—1912–13	Single-wire light-valve, with microscope for enlarging wire
	14—1913–14	Three to one frame revolving cylindrical lens film-gate assembled on demonstration stand to show application of principle. (Handwheel, stand, base, thumbscrew, and lock nut are new)
	15—1913–14	Light-valve with oil damper (magnet missing); light was projected through small round window
	16—1910	Electrodiamagnetic recording light-valve, with single vibrating wire (replica original valve in Lauste sound-recording machine)
	17—1909–10	String recorder, oscillograph principle using optical slit, permanent magnet, single vibrating wire, oil damper. This was Lauste's first experimental string recorder
	18—1913–14	Microphonic relay for sound amplification; diaphragm and glass rod are new
	19—1912–14	Microphonic relay (horizontal) used in amplification magnet

Accession No.	Source	Material
		with clamping bar and nut; two coils, iron cores, and diaphragm are new
	20—1913–14	Microphonic relay (vertical) used for amplification; complete receiver, electrical magnet; adjustment bar and slide are new
	21—1912	Lamp holder for gas-filled lamp, used by Lauste to replace singing arc, original
	22—1906–14	Selenium cells, used by Lauste in recording and reproducing sound between 1906–14
	23—1906–14	Selenium cells (B. Bildwell cell) used by Lauste
	24—1906–14	Selenium cells (A. Presser Ernst cell) used by Lauste
	25—1906–14	Selenium cells used by Lauste
	26—1909–10	Grate light-valve (oscillator missing)
	27—1908–9	Three types grate light-valves for recording sound only (all reconstructed)
	28—1900	Grate light-valve for recording in variable-density
	29—1911–12	Ducretet transformer, adjustable core and primary used by Lauste in connection with light-valve (original)
	30—1911–12	Ducretet transformer, adjustable core and primary used by Lauste in connection with light-valve (reconstructed with old parts)
	31—1908	Ruhmer photographophone bought by Lauste in 1908
	32—1908	Original arc lamp used by Ernest Ruhmer in his recording of sound waves, called the "singing arc"
	33—1908	Selenium cell used by Ernest Ruhmer in his photographophone
	34—1908	Ruhmer photographophone, reconstructed by Lauste (all new)

Accession No.	Source	Material
	35—1911–12	Early specimen of film used by Lauste to record sound and scene and sound only, with his apparatus, showing picture and sound; original
	36—1898	Jean Acme Le Roy Collection, Carpentier-Lumière "Cinematolob" with original mechanism, spare parts
	37—	Jean Acme Le Roy Collection, Biograph No. 6 head
	38—	Jean Acme Le Roy Collection, Cinematolob, original mechanism with attachments by Le Roy
	39—	Jean Acme Le Roy Collection, Le Roy acmegraph head
	40—	Jean Acme Le Roy Collection, J. B. Colt Criterioscope, head
	41—1893	Jean Acme Le Roy Collection, Edison projecting Kinetoscope head
	42—1895	Jean Acme Le Roy Collection, Edmund Kuhn camera built by Honeck, New York, 1895; used film 2 $^{7}/_{16}$ wide
	43—1910	Lauste continuous printing machine for sound, entire outside refinished
	44—1913	Lauste condenser loud speaker, original
	45—1912–13	Lauste sound and scene camera
	46—1910–11	Camera projector for sound and scene, Pathé original film, sprockets, intermittent motion, drive shaft with gear, flywheel, intermittent gear, lens holder, pressure cover with bearings for film sprockets
	47—1908–09	Lauste sound reproducer
	48—1911–12	Lauste sound recorder
	49—1908–09	Lauste jacket to hold lens used in sound recording (original)
	50—1912–13	Lauste original projector head (modified Pathé head)

Accession No.	Source	Material
	51—1912–13	Lauste sound and scene projector
		14 Portfolios relating to E. A. Lauste; scrapbooks, Lauste's history of his own work, patent suits, articles, *etc.*
134910	Lauste	2 Pairs head-phones, 1 copy *Nouvel Art Cinematographie,* 1 copy Honorary Membership SMPE, 1 copy *Variety,* 1 copy *Sunday News,* 1 photo of Doublie, first operator for Lumière Bros., 1895, and Lauste
139045	Soc. Mot. Pict. Eng.	1 Edison spool-bank projecting Kinetoscope; No. 429, 1897
		12 Films, photographs, *etc.*
147084	Mot. Pict. Operators Protec. Union	1 Simplex projector
		1 Powers Cameragraph head
147528	Alton J. Pratt (Warner Bros.)	1 Pathé projector head
147537	Frederick Gooch	1 Edison Kinetoscope motion picture head, 1908
148290	Frederick Gooch	1 Powers Cameragraph head No. 5 with projection lens
149912	Frederick Gooch	1 Baird projector, no lens
		1 Graphoscope No. 1679 projector, no lens
150153	Frederick Gooch	1 Bausch & Lomb projection lens, No. 14798
		1 Gundlach-Manhattan Optical Co. projection lens
		1 N. Powers Co. intermittent
152678	Rudolph Schneider	1 Lumière Cinematographe motion picture projector with lens No. 71, 1895
152762	G. J. Badgley	1 Demeny motion picture camera, 1907; made by L. Gaumont
156475	Leon F. Douglas	1 Piece of motion picture film in color in display case, invented by Douglas more than 25 years ago
157202	Betty B. Heal	1 Motion projection head
148846	Francis Marsten	1 Universal motion picture camera No. 16 made by hand in 1914, 1 mag., no lens

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

American Cinematographer

21 (October, 1940), No. 10

Exposure Meter Accuracy Means Uniform Results (pp. 445–447)	R. E. Kidd
Bill Wade Discusses Artificial Lighting (pp. 466–467)	W. Wade

British Journal of Photography

87 (September 13, 1940), No. 4193

Progress in Colour (pp. 449–450)

87 (September 20, 1940), No. 4194

Progress in Colour (pp. 459–461)

87 (September 27, 1940), No. 4195

Progress in Colour (pp. 468–470)

87 (October 4, 1940), No. 4196

Progress in Colour (pp. 482–483)

Communications

20 (October, 1940), No. 10

Some Notes on Vibratory Momentum and Groove Skating in Disc Reproduction (pp. 22, 25–28)	J. C. Parvey

Educational Screen

19 (October, 1940), No. 8

Motion Pictures—Not for Theaters, Pt. 20 (pp. 333–336)	A. E. Krows

Institute of Radio Engineers, Proceedings

28 (August, 1940), No. 8

Quality in Television Pictures (pp. 343–350)	P. C. Goldmark and J. N. Dyer
Some Factors Affecting the Choice of Lenses for Television Cameras (pp. 369–374)	H. B. DeVore and H. Iams

28 (September, 1940), No. 9

Some Problems of Disk Recording (pp. 389–398)	S. J. Begun

International Photographer

12 (October, 1940), No. 9

What Is a Soundie? (p. 11)

Skinner Recorder (pp. 17–18)

12 (November, 1940), No. 10

Paducah Spotlight (pp. 13, 25)

Latin American Markets (pp. 18–19) — N. D. GOLDEN

Motion Picture Herald

141 (October 26, 1940), No. 4

MPPDA Launches Special Trailer for Exhibitor Tieups in Schools (p. 25)

Photographische Industrie

38 (June 12, 1940), No. 24

Das Petzval-Voigtlander-Objektiv und seine Fortentwicklung als Projektions-System, IV (Further Development of the Petzval-Voigtlander Lens in the Projection System) (pp. 369–371) — K. PRITSCHOW

38 (June 26, 1940), No. 26

Das Petzval-Voigtlander-Objektiv und seine Fortentwicklung als Projektions-System, V (Further Development of the Petzval-Voigtlander Lens in the Projection System) (pp. 397–399) — K. PRITSCHOW

38 (July 10, 1940), No. 28

Das Petzval-Voigtlander-Objektiv und seine Fortentwicklung als Projektions-System, VI (Further Development of the Petzval-Voigtlander Lens in the Projection System) (pp. 425–426) — K. PRITSCHOW

38 (July 31, 1940), No. 31

Wissenschaftliche Kinematographic vor neuen Zielen (Scientific Motion Pictures for New Purposes) (pp. 487–488)

38 (August 14, 1940), No. 33

Filter-Verwendung für Farben-Schmalfilmaufnahmen und Projektion (Use of Filters in Taking and Projecting Substandard Color Films) (pp. 495–496)

38 (September 4, 1940), No. 36

Maschinelle Entwicklung des Kinofilms und die Kopienherstellung (Machine Development of Motion Picture Films and Printing) (pp. 538–540) — P. HANNEKE

38 (September 11, 1940), No. 37

Sprossenschrift-Aufnahme und Kopie mit UV-Licht (Variable Density Taking and Printing with Ultraviolet Light) (pp. 549–551)

HIGHLIGHTS OF THE FALL CONVENTION

HOLLYWOOD-ROOSEVELT HOTEL, HOLLYWOOD, CALIF.
OCTOBER 21–25, 1940

A number of outstanding features marked the 1940 Fall Convention of the Society at Hollywood, including visits to three of the large studios. The attendance at all the sessions, except some of the morning sessions, was large, and at the Friday evening television session the number of members and guests was in excess of 400.

On the morning of Monday, October 21st, the Forty-seventh Annual Convention of the Society opened at the Hollywood-Roosevelt Hotel. The first part of the first session was given over to reports of the Convention Arrangements Committee, the Financial Vice-President, the Engineering Vice-President, and the Editorial Vice-President, followed by a brief address of welcome by President Williford. Of special interest in this session was a paper by J. W. McNair of the American Standards Association, discussing the question of "American Standards and Their Place in the Motion Picture Industry." Following this Mr. R. G. Linderman, member of the British Kinematograph Society, recently returned from England, read a report of the BKS describing their activities in the motion picture field under the exigencies of the present war. Messrs. H. J. Chanon and F. M. Falge of the General Electric Company described the technic and applications of "Black Light for Theater Auditoriums." Demonstrations were given of the various forms of light-sources and filters used, as well as the various kinds of fluorescent materials applied to the surfaces or fabrics to be illuminated.

At noon, the usual informal get-together luncheon was held in the Florentine Room of the hotel, Mr. Williford presiding. A brief address of welcome to the members and guests of the Society was made by the Hon. Fletcher Bowron, Mayor of the City of Los Angeles, followed by an address by Mr. Frank Capra, Vice-President of the Academy of Motion Picture Arts and Sciences. Mr. Capra's speech was devoted to the relation between the activities of the engineering branch of the motion picture industry and the branches represented by the producers, directors, and writers, emphasizing the fact that the achievements possible in the production of motion pictures is very dependent upon the means supplied to the producers, directors, and others by the engineers. The luncheon ended with a number of songs by Miss Mary Martin, courtesy of Paramount Pictures, Inc.

On the afternoon of Monday, October 21st, a session on acoustics was held in the Blossom Room of the hotel under the chairmanship of Mr. D. E. Hyndman. Notable among the presentations at this session was a demonstration of make-up technic by Mr. Jack Dawn of Metro-Goldwyn-Mayer Studios. Mr. Dawn went through the process of applying make-up to his own face, demonstrating the use

of plastic materials for molding or "sculpturing" the facial expressions and contours required in character make-up.

The remainder of the session included a report of the SMPE Standards Committee by Mr. D. B. Joy, Chairman, and a symposium of three papers dealing with the acoustics of theaters and review rooms. The "Recommendations on Theater Acoustics from the Research Council Theater Standardization Committee" by J. K. Hilliard, Chairman, and "An Outline of the Work of the Academy Research Council Sub-Committee on Acoustical Characteristics" by Jack Durst, Chairman, constituted two contributions to the program by the technical committees of the Research Council. A paper by Mr. D. P. Loye of Electrical Research Products, Inc., dealt with the acoustical design features of studio sound-stages, monitor rooms, and review rooms, discussing in considerable detail the desirable acoustics for recording in such sound-stages and rooms.

The evening of the first day was devoted to a sound session under the chairmanship of Mr. L. L. Ryder, Chairman of the Pacific Coast Section of the Society. A paper by Messrs. S. Read, Jr., and E. W. Kellogg of the RCA Manufacturing Company, discussed the question of "Stability of Synchronous Motors," pointing out that the various types of motors used differ widely in their ability to resist load irregularities and in their tendency to oscillate when a disturbance occurs. The characteristics of the various types of motors were discussed. Mr. E. W. Kellogg also presented a paper on the subject of "Ground-Noise-Reduction Systems," the purpose of which was to formulate a statement of the desired characteristics of ground-noise-reduction systems in terms of such factors as promptness of opening, peak reading, and filtering. A number of circuits were described that had been proposed for improving the filtering without sacrificing the rapidity of opening or closing.

Messrs. I. J. Wilkinson and W. Hamilton, of RKO Radio Pictures, Inc., presented a paper entitled "Editing a Motion Picture" in which were described some of the mechanical and artistic elements involved in the process of editing. Since so little material has been published on this phase of motion picture production, the paper is intended to serve as a preliminary to a study on a larger scale. A demonstration film was projected to illustrate various editing technics and to show the possibility of their use as a means of drastically altering the original story and dramatic conception.

The morning of Tuesday, October 22nd, was devoted to a session on sound under the chairmanship of Mr. H. G. Tasker. The first two papers were devoted to studies and descriptions of the line microphone, which was described by Mr. H. F. Olson of the RCA Manufacturing Company as a microphone consisting of a large number of small tubes with open ends, as pick-up points, equally spaced along a line, and the other ends connected by means of a common junction to a transducer element for converting the sound vibrations converging upon the junction into corresponding electrical variations. Several types of line microphones with the useful directivity along the line axis were described.

Following Mr. Olson's presentation, Mr. L. J. Anderson of the RCA Manufacturing Company, in a paper entitled "A Line Type of Microphone for Speech Pick-Up," discussed the development of a line microphone having directional characteristics that are relatively independent of frequency and of such size as to be readily portable.

Messrs. F. L. Hopper of Electrical Research Products, Inc., and F. F. Romanow of the Bell Telephone Laboratories discussed "Methods of Calibrating Microphones," *i. e.*, of determining the performance characteristics of microphones by acoustical measurements. The accuracy of the methods was discussed as well as the correlation of a microphone's performance as determined by acoustical measurement and by listening tests.

The meeting closed with a report of the Museum Committee, H. T. Cowling, Chairman, in which was described briefly the equipment in the motion picture exhibit at the Smithsonian Institution at Washington. A plea was made for the assistance of the membership of the Society in acquiring additional exhibits for the Museum.

Shortly after noon the members of the Society and their guests were tendered a luncheon by the Twentieth Century-Fox Film Corporation at their Cafe de Paris on the Studio lot. The luncheon and visit to the studios were made possible through the courtesy of Mr. Darryl Zanuck, President of the Twentieth Century-Fox Film Corporation. The committee in charge of the visit consisted of Mr. Harry Brand, Director of Publicity, Mr. E. H. Hansen, Director of Recording, and Mr. Raymond Dannenbaum of the Publicity Department.

The trip through the studio included an inspection of the recording rooms, a demonstration of mixing in a scene from the forthcoming *Mark of Zorro*, and a demonstration of colored background projection by a new triple-head projector. The new silent "Twentieth Century Camera," described in a technical paper in a subsequent session of the convention, was viewed in action on one of the sets in work.

The visit to the studio closed with a tour of the portions of the lot where are located the sets used in producing many outstanding feature pictures.

In the evening a sound-recording session was held under the chairmanship of Major Nathan Levinson. The session opened with a description of a new mirror light-modulator by W. R. Goehner of the Bell Telephone Laboratories, followed by a companion paper by R. W. Benfer and G. T. Lorance of Electrical Research Products, Inc., describing in detail a 200-mil variable-area modulator. The system is applied particularly to recording, with noise-reduction Class *A* push-pull track comprising two standard bilateral tracks, one of which is located in accordance with the dimensional standards for single track. While this has been its principal use to date, it is readily adaptable to recording other types of track.

The paper by Messrs. D. MacKenzie and W. J. Albersheim of Electrical Research Products, Inc., comprised an "Analysis of Sound-Film Drives," and Messrs. W. K. Grimwood and O. Sandvik of the Eastman Kodak Company described "An Investigation of Some Factors Influencing Volume Range in Photographic Sound Recording." The latter was an extension of an earlier investigation of background noise, and dealt more specifically with the relation between volume range, the type of photographic materials used, and the sensitometric conditions under which they were used. A brief study of the effect of the spectral quality of the radiation used in recording and printing was also included.

The session closed with a description by C. Flannagan of Electrical Research Products, Inc., of the stereophonic recording and reproducing system demonstrated several months ago at Carnegie Hall at New York and also at the Pantages Theater at Hollywood.

At the meeting of the Board of Governors held on October 20th the name of Dr. Lee de Forest was proposed by the Historical Committee and approved by the Board of Governors as an Honorary Member of the Society. At this session of the Convention, therefore, a quorum being present, a ratifying vote of the Society was taken, with unanimous approval.

The Wednesday morning session was devoted to studio subjects, under the chairmanship of Mr. J. I. Crabtree. The meeting opened with the Report of the Studio Lighting Committee, E. C. Richardson, Chairman, which reported a number of changes of technic during the past year in the use of studio lighting equipment. Dr. C. R. Daily described a dolly-mounted, high-quality, two-way horn system for play-back and announcing service on production recording stages, and Mr. J. Arnold gave an account of a new "M-G-M Mobile Camera Crane."

Producing *March of Time* pictures requires equipment of great portability and simplicity of operation, while yet retaining good quality. Mr. D. Y. Bradshaw of March of Time, Inc., described the equipment used for this purpose and discussed the means adopted for overcoming various handicaps in the system. Mr. R. Van Slyker next gave a description of Hollywood's low-temperature sound-stage, one of the ice-storage buildings of the California Consumers Corp., which has been adapted for the production of pictures requiring realistic snow and ice scenes. The problem of heat from the lighting equipment, particularly with respect to Technicolor productions, and the effect of this heat upon the refrigeration requirements, were discussed in some detail. The morning session closed with the Report of the Committee on Preservation of Film, J. G. Bradley, Chairman, which contained reports of several sub-committees on the handling and winding of film, its safe and economical storage, the size of vent required per unit weight of film, microfilm testing methods, and printers for old and shrunken film.

The afternoon of Wednesday was left open.

The 47th Semi-Annual Banquet of the Society was held in the Blossom Room of the Hotel in the evening (October 23rd), about 400 persons attending. A detailed description of the proceedings of the banquet is given elsewhere in this issue of the JOURNAL. After introducing the officers and governors present, President Williford officiated at the presentations of the Progress Medal and Journal Award to Mr. Walt Disney and Dr. Robert R. McMath, respectively, and introduced Dr. Lee de Forest, who had been elected an Honorary Member of the Society on the preceding day. A half hour of entertainment was provided by Rudy Valee and others.

The morning session of Thursday, October 24th, was devoted to projection matters under the chairmanship of Mr. Herbert Griffin. In addition to an extensive report by the Theater Engineering Committee, papers were presented by Messrs. J. E. McAuley and R. O. Walker on a new type of high-intensity projector lamp and a molded plastic screen. This screen is molded of a flexible plastic material, without seams, up to 30 feet wide.

A visit was made in the afternoon to the studios of RKO Radio Pictures, Inc., by courtesy of Mr. J. R. McDonough, Vice-President. The visit was under the direction of Messrs. J. O. Aalberg, Vern Walker, and Van Nest Polglase, and opened with a brief showing on one of the stages of pictures employing interesting process shots, after which the group was escorted through the Process Department and shown a number of the methods used in producing various trick effects.

A demonstration was given of the method of photographing the occupants inside an automobile so as to show the receding scenery behind the back window of the car.

The Thursday evening session was held at the Walt Disney Studio Theater under the chairmanship of Mr. Emery Huse. Prior to the meeting, members and guests of the Society had dinner in the new Disney Cafe on the lot.

The meeting opened with a description of "The New Walt Disney Studio," by Messrs. W. G. Garity and J. L. Ledeen. This beautiful lot and group of buildings have been built during the past year or so and represent the most up-to-date advances in studio design. The paper described the layout of the lot with particular respect to cartoon production and also gave an account of the various departments required for the production of cartoons. Some mention was made also of the new Disney feature production, *Fantasia*. The current practice in producing motion pictures is to supply a musical accompaniment to the picture. *Fantasia* reverses the process: a visual accompaniment is provided for the music, which in this case consisted of a group of classical orchestral pieces. Both cartoon and live photography are employed.

Next followed a very interesting presentation by Messrs. D. B. Clark and G. Laube of the new Twentieth Century-Fox camera; a new slating and cueing device; and a new photoelectric method of rating the speed of lenses. The presentation had previously been recorded on film, both photographically and with sound, and instead of making the presentation orally, the authors allowed the film to make it for them. The new camera is designed primarily to reduce noise, and embodies many conveniences and devices assisting in the reduction of time and cost in production. The system of rating the speed of lenses is based upon the actual light transmitted through the lens, referred to a standard calibration against which all lenses are compared. The session closed with a description by R. H. Talbot of a new method of preventing film abrasion and oil mottle, which consisted in the application to either or both sides of 16 or 35-mm films of a lacquer, the function of which is to absorb all the ordinary cinch marks and other abrasions commonly found on films in service. When the lacquer has been removed and replaced by a fresh coat, the film is found to be in essentially as good condition as when new. In addition, the lacquer, because of its glossy surface, eliminates the mottle or flicker upon the screen due to oil on the film.

The Friday morning session was devoted to laboratory problems, under the chairmanship of Mr. A. C. Downes. It opened with a Report of the Committee on Non-Theatrical Equipment and a discussion of "Some Laboratory Problems in Processing 16-Mm Black-and-White and Color-Films," by W. H. Offenhauser.

One of the contributing factors to sound-track degradation is sprocket-hole modulation, which results from non-uniform action of developer around the perforation holes during processing. Messrs. M. Leshing, T. Ingman, and K. Pier discussed the problem and pointed out that the chief remedy lies in adequate turbulation. Data showing the decrease of this distortion with increased turbulation, and photographs showing various types of sprocket-hole modulation, were presented. A complete description of the turbulation methods employed at the Twentieth Century-Fox laboratory was disclosed.

Mr. C. R. Sawyer officiated as Chairman of the laboratory session held on Friday afternoon, which included papers on "Effects of Developer Agitation"

and "The Elimination of Hypo from Film," respectively, by Messrs. C. E. Ives and C. W. Jensen, and Messrs. J. I. Crabtree, G. T. Eaton, and L. E. Muehler. The measurement of photographic printing density was discussed by J. G. Frayne, who pointed out that when the spectral sensitivity of positive film is simulated by a suitable combination of phototube and optical filter in the integrating sphere densitometer, the printing density of any type of negative, irrespective of grain size, with any type of base may be accurately determined.

The afternoon closed with a paper on "Remote Control Incandescent Television Lighting" by W. C. Eddy, a further discussion of the material presented by Mr. Eddy at the Atlantic City Convention last Spring.

The evening session was devoted to television, under the chairmanship of President Williford. An outstanding feature of the Convention was a description during this session by Dr. V. K. Zworykin of "The RCA Electron Microscope." Dr. Zworykin described the elementary principles of electron optics and their application to the electron microscope, showed views of the electron microscope, now in use at several research laboratories, and also exhibited on the screen a number of enlarged photographs of microbes and non-filterable viruses. It was said that the magnification achieved by the electron microscope may run as high as 40,000, achieving resolution of particles as small as 50 Ångstrom units.

During the convention, an exhibit of newly developed equipment was held on the mezzanine of the hotel. Companies represented in the exhibit were:

Electrical Research Products, Inc.
Holmes Projector Co.
National Theater Supply
Moviola Company
Norman B. Neely
RCA Manufacturing Co.
Eastman Kodak Co.
Mole-Richardson Co.
Lansing Mfg. Co.

ACKNOWLEDGMENTS

The Society wishes to acknowledge its gratitude to the large number of persons and companies who collaborated in providing the various facilities for the Convention.

Acknowledgment is due also to the Fox West Coast Theater Corp., Warner Brothers Theaters, Inc., and Rodney Pantages, Inc., for passes issued to the Convention delegates to Grauman's *Chinese* and *Egyptian Theaters*, Warner's *Hollywood Theater*, and Pantages' *Hollywood Theater*.

PROGRAM OF THE HOLLYWOOD CONVENTION*

MONDAY, OCTOBER 21st

10:00 a.m. **General and Business Session; E. A. Williford,** *Chairman.*
Report of the Convention Arrangements Committee; W. C. Kunzmann, *Convention Vice-President.*
Report of the Financial Vice-President; A. S. Dickinson.
Report of the Engineering Vice-President; D. E. Hyndman.
Welcome by the President; E. A. Williford.
Society Business.
Election of Officers of the Society for 1941.
"American Standards and Their Place in the Motion Picture Industry;" J. W. McNair, American Standards Association, New York, N. Y.
"Activities of the British Kinematograph Society during Wartime."

12:00 "Black Light for Theater Auditoriums;" H. J. Chanon, General Electric Company, Cleveland, Ohio, and F. M. Falge, General Electric Company, Los Angeles Calif.

12:30 p.m. **Informal Get-Together Luncheon; E. A. Williford,** *Chairman.*
Address of Welcome by the Honorable Fletcher Bowron, Mayor of the City of Los Angeles.
Address by Mr. Frank Capra, Vice-President of the Academy of Motion Picture Arts and Sciences, Hollywood, Calif.

2:00 p.m. **Acoustics Session; D. E. Hyndman,** *Chairman.*
Report of the Standards Committee; D. B. Joy, *Chairman.*
"Recommendations on Theater Acoustics from the Research Council Theater Standardization Committee;" J. K. Hilliard, *Chairman.*
An Outline of the Work of the Academy Research Council Sub-Committee on Acoustical Characteristics; Jack Durst, *Chairman.*
"Acoustic Design Features of Studio Stages, Monitor Rooms, and Review Rooms;" D. P. Loye, Electrical Research Products, Inc., Hollywood, Calif.
"Demonstration of Make-Up Technic;" Jack Dawn, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

8:00 p.m. **Sound Session; L. L. Ryder,** *Chairman.*
"Operation of the Variable-Intensity Recording System;" C. W. Faulkner, Twentieth Century-Fox Film Corp., Hollywood, Calif., and C. N. Batsel, RCA Manufacturing Company, Hollywood, Calif.
"Ground-Noise-Reduction Systems;" E. W. Kellogg, RCA Manufacturing Company, Camden N. J.

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* As actually followed in the sessions.

"Stability of Synchronous Motors;" S. Read, Jr., and E. W. Kellogg, RCA Manufacturing Co., Camden, N. J.

"Editing a Motion Picture;" I. J. Wilkinson and W. Hamilton, RKO Radio Pictures, Inc., Los Angeles, Calif. (*Demonstration.*)

"A Monochromatic Variable-Density Recording System;" O. L. Dupy and J. K. Hilliard, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

TUESDAY, OCTOBER 22nd

10:00 a.m. **Sound Session; H. G. Tasker,** *Chairman.*

"Line Microphones;" H. F. Olson, RCA Manufacturing Company, Camden, N. J.

"A Line Microphone for Speech Pick-Up;" L. J. Anderson, RCA Manufacturing Company, Camden, N. J.

"A Method of Calibrating Microphones;" F. L. Hopper, Electrical Research Products, Inc., Hollywood, Calif., and F. F. Romanow, Bell Telephone Laboratories, Inc., New York, N. Y.

"General and Design Considerations of Low-Noise Microphones;" A. L. Williams and H. G. Baerwald, Brush Development Corp., Cleveland, Ohio.

"Stabilized Crystal Disk Recording Cutter;" S. J. Begun, Brush Development Corp., Cleveland, Ohio.

1:30 p.m. **Studio Visit and Luncheon.**

Luncheon and visit to the Studios of the Twentieth Century-Fox Film Corp., as guests of the Studio, by courtesy of Mr. Darryl Zanuck, *President.* Committee in Charge: Mr. Harry Brand, *Director of Publicity;* Mr. E. H. Hansen, *Director of Recording;* and Mr. Raymond Dannenbaum, of the Publicity Department.

The luncheon was held in the Cafe de Paris at the Westwood Studio. The trip included a preview in action of the new silent Twentieth Century camera, described in the Thursday evening technical session by Messrs. D. B. Clark and G. Laube, in addition to other points of technical interest.

8:00 p.m. **Sound Recording Sessions; N. Levinson,** *Chairman.*

"A New Mirror Light-Modulator;" W. R. Goehner, Bell Telephone Laboratories, New York, N. Y.

"A 200-Mil Variable-Area Modulator;" R. W. Benfer and G. T. Lorance, Electrical Research Products, Inc., Hollywood, Calif.

Proposal of Dr. Lee De Forest as Honorary Member of the Society, by the Historical Committee, E. W. Theisem, *Chairman.*

"Analysis of Sound-Film Drives;" D. MacKenzie and W. J. Albersheim, Electrical Research Products Corp., New York, N. Y.

"An Investigation of Some Factors Influencing Volume Range in Photographic Sound Recording;" W. K. Grimwood and O. Sandvik, Eastman Kodak Co., Rochester, N. Y.

"A Stereophonic Recording and Reproducing System;" C. Flannagan, Electrical Research Products, Inc.; New York, N. Y.

WEDNESDAY, OCTOBER 23rd

10:00 a.m. **Studio Session; J. I. Crabtree,** ***Chairman.***
Report of the Studio Lighting Committee; E. C. Richardson, Chairman.
"An Improved Playback Horn Equipment;" C. R. Daily, Paramount Pictures, Inc., Hollywood, Calif.
"An Improved Mixer Potentiometer;" K. B. Lambert, Metro-Goldwyn-Mayer Studios, Culver City, Calif.
"Production-Quality Sound with Single-System Portable Equipment;" D. Y. Bradshaw, March of Time, New York, N. Y.
"Hollywood's Low-Temperature Sound-Stage;" R. Van Slyker, Hollywood Calif. (*Demonstration.*)
Report of the Committee on Preservation of Film; J. G. Bradley, Chairman.

2:00 p.m. **Open Afternoon.**

8:30 p.m. **47th Semi-Annual Banquet and Dance.**
Introduction of Officers-Elect for 1941.
Presentation of the SMPE Progress Medal.
Presentation of the SMPE Journal Award.
Entertainment and Dancing.

THURSDAY, OCTOBER 24th

10:30 a.m. **Projection Session; H. Griffin,** ***Chairman.***
Report of the Theater Engineering Committee; A. N. Goldsmith, *Chairman.*
"A New Condenser-Type High-Intensity Projector Arc Lamp;" J. E. McAuley, J. E. McAuley Manufacturing Company, Chicago, Ill.
"A Molded Plastic Screen with Contoured Surface;" R. O. Walker, Walker-Amerian Corp., St. Louis, Mo.
"Some Developments in 8-Mm High-Intensity Positive Carbons;" D. B. Joy, National Carbon Co., Fostoria, Ohio.
"Improved Motor Drive for Self-Phasing of Process Projection Equipment;" H. G. Tasker, Paramount Pictures, Inc., Hollywood, Calif.
"MGM Mobile Camera Crane;" J. Arnold, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

2:30 p.m. **Studio Visit.**
A visit to the Studios of RKO Radio Pictures, Inc., by courtesy of Mr. J. R. McDonough, *Vice-President.* Messrs. J. O. Aalberg, Vern Walker, and Van Nest Polglase were in charge of the visit.

6:00 p.m. **Studio Visit.**
A visit to the Walt Disney Studio, arranged by the courtesy of Mr. W. E. Garity, *Studio Manager;* visit in charge of Mr. C. O. Slyfield, *Sound Director.*

8:00 p.m. **Walt Disney Studio Theater; General Session; E. Huse,** ***Chairman.***

"The New Walt Disney Studio;" W. E. Garity and J. L. Ledeen, Walt Disney Studios, Hollywood, Calif.

"Twentieth Century Camera;" G. Laube, Twentieth Century-Fox Film Corp., Holywood, Calif. (*Demonstration.*)

"Electrooptical Slating and Cueing Device;" D. B. Clark, Twentieth Century-Fox Film Corp., Hollywood Calif. (*Demonstration.*)

"Photoelectric Method for Rating the Light-Speed of Lenses;" D. B. Clark, Twentieth Century-Fox Film Corp., Hollywood, Calif. (*Demonstration.*)

"Scene-Slating Attachment for Motion Picture Cameras;" F. C. Gilbert, Paramount Pictures Corp., Hollywood, Calif. (*Demonstration.*)

"A New Treatment for the Prevention of Film Abrasion and Oil Mottle;" R. H. Talbot, Eastman Kodak Company, Rochester, N. Y. (*Demonstration.*)

FRIDAY, OCTOBER 25th

10:00 a.m. **Laboratory Session; A. C. Downes,** ***Chairman.***

Report of the Committee on Non-Theatrical Equipment; J. A. Maurer, *Chairman.*

"Some Laboratory Problems in Processing 16-Mm Black-and-White and Color-Films;" W. H. Offenhauser, Jr., Precision Laboratories, Inc., New York, N. Y.

"Reduction of Sprocket-Hole Modulation in Film Processing;" M. Leshing, T. Ingman, and K. Pier, Twentieth Century-Fox Film Corp., Hollywood Calif. (*Demonstration.*)

"Some Observations on Latent Image Stability of Motion Picture Film;" K. Famulener and E. Loessel, Agfa Ansco Company, Binghamton, N. Y.

Report on the Activities of the Inter-Society Color Council; R. M. Evans, Chairman of SMPE delegates to the ISCC.

"Quarter-Wave Method of Loud Speaker Testing;" S. L. Reiches, Cleveland, Ohio.

2:00 p.m. **Laboratory Session; C. R. Sawyer,** ***Chairman.***

"The Effect of Developer Agitation on Density Uniformity and Rate of Development;" C. E. Ives and C. W. Jensen, Eastman Kodak Co., Rochester, N. Y.

"The Elimination of Hypo from Motion Picture Film;" J. I. Crabtree, G. T. Eaton, and L. E. Muehler, Eastman Kodak Co., Rochester, N. Y.

"The Measurement of Photographic Printing Density;" J. H. Frayne, Electrical Research Products, Inc., Hollywood, Calif.

"Negative Exposure Control;" D. Norwood, Hollywood, Calif.

"Remote Control Incandenscent Television Lighting;" W. C. Eddy, Balaban & Katz Corp., Chicago, Ill.

8:00 p.m. **Television Session; E. A. Williford,** ***Chairman.***

"Photographic Aspects of Television Operation;" H. R. Lubcke, Don Lee Broadcasting System, Los Angeles, Calif.

Report of the Television Committee; P. C. Goldmark, ***Chairman.***

"The RCA Electron Microscope;" V. K. Zworykin, RCA Manufacturing Co., Camden, N. J.

"Televising the Political Conventions of 1940;" H. See, National Broadcasting Co., New York, N. Y.

"Problems in Television Resolution;" C. F. Wolcott, Gilfillan Brothers, Inc., Los Angeles, Calif.

SOCIETY ANNOUNCEMENTS

OFFICERS OF THE SOCIETY FOR 1941

The results of the recent election of Officers of the Society for 1941 are as follows:

***President:* EMERY HUSE
***Executive Vice-President:* HERBERT GRIFFIN
***Editorial Vice-President:* ARTHUR C. DOWNES
***Convention Vice-President:* W. C. KUNZMANN
**Secretary:* PAUL J. LARSEN
**Treasurer:* GEORGE FRIEDL, JR.
***Governor:* MAX C. BATSEL
***Governor:* L. L. RYDER

Officers and Governors of the Society, whose terms do not expire until December 31, 1941, are as follows:

**Engineering Vice-President:* D. E. HYNDMAN
**Financial Vice-President:* A. S. DICKINSON
**Governor:* ALFRED N. GOLDSMITH
**Governor:* A. C. HARDY

Due to the election of Mr. Herbert Griffin to the Executive Vice-Presidency, beginning January 1, 1941, Mr. Griffin resigned from his position as elected governor and Mr. T. E. Shea was elected by the Board of Governors to fill the vacancy for the unexpired term of one year.

The three remaining governors are the chairmen of the three local Sections. Mr. R. O. Strock has been elected Chairman of the Atlantic Coast Section and Dr. J. G. Frayne, Chairman of the Pacific Coast Section. The results of the Mid-West Section elections will be announced as soon as they are available.

ATLANTIC COAST SECTION

The results of the election of officers and managers of the Atlantic Coast Section for 1941 are as follows:

**Chairman:* R. O. STROCK
**Secretary-Treasurer:* J. A. MAURER
***Managers:* P. C. GOLDMARK
H. E. WHITE
WM. H. OFFENHAUSER
**Managers:* H. B. CUTHBERTSON
F. E. CAHILL
J. A. NORLING

* Term expires December 31, 1941.
** Term expires December 31, 1942.

The remaining manager of the Section is P. J. Larsen, *Past-Chairman.*

PACIFIC COAST SECTION

The results of the recent election of officers and managers of the Pacific Coast Section for 1941 are as follows:

**Chairman:* J. G. FRAYNE
**Secretary-Treasurer:* C. W. HANDLEY
***Managers:* F. J. DURST
B. KREUZER
S. P. SOLOW

Other members of the Board of Managers are:

*H. W. MOYSE
*R. W. REMERSHEID
*P. MOLE

whose terms have one year to run. The remaining member of the Board is L. L. Ryder, who will be *Past-Chairman.*

The new Officers and Managers assume their positions on January 1, 1941.

PROGRESS AND JOURNAL AWARDS OF THE SOCIETY

It is a requirement each year after the presentation of the Progress Medal and the Journal Award certificate at the Fall Convention of the Society to publish in the JOURNAL a list of the names of all those who have thus far received these awards. The lists follow:

Progress Medal

1935 E. C. WENTE
1936 C. E. K. MEES
1937 E. W. KELLOGG
1938 H. T. KALMUS
1939 L. A. JONES

Journal Award

1934 P. A. SNELL
1935 L. A. JONES and J. H. WEBB
1936 E. W. KELLOGG
1937 D. D. JUDD
1938 K. S. GIBSON
1939 H. T. KALMUS

* Term expires December 31, 1941.
** Term expires December 31, 1942.

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OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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